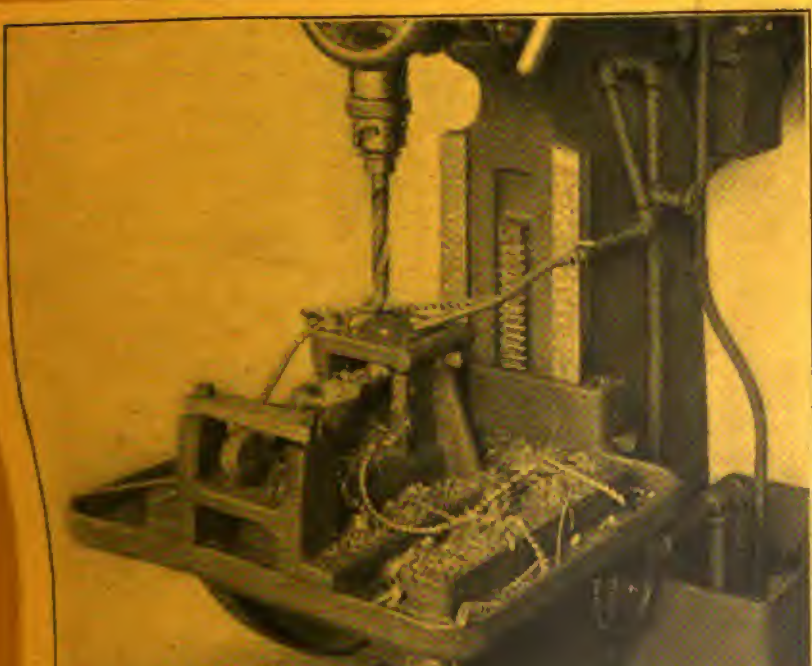
PRICE 25 CENTS

DRILL JIGS

PRINCIPLES OF DESIGN—EXAMPLES FROM PRACTICE DIMENSIONS OF JIG BUSHINGS

THIRD EDITION



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NUMBER 3

DRILL JIGS

THIRD EDITION

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CHAPTER I

ELEMENTARY PRINCIPLES OF DRILL JIGS*

The reasons for the use of jigs may be summed up under three heads, the order in which they are stated representing fairly well the frequency of occurrence, though not necessarily the importance, of these reasons: First, reduction of cost; second, duplication; third, accuracy.

Let us first consider the question of cost. As no article can, as a rule, be sold in open competition with similar articles unless its cost is somewhat proportionate to the quality of its competitors, commercial considerations demand that the cost be kept as low as possible, while the quality be kept as high as possible; and jigs are one of the chief agents of this in metal work. When a jig is considered, the first thing to be settled is whether it can be made to pay, and if so, how much. The answer to this often involves very many other questions, but can generally, if not always, be resolved into computations based upon the number of pieces to be made, and the probable cost of labor per piece when made with and without a jig, and the cost of the jig, including maintenance. Also the fact that often a much less valuable machine, or one less busy, can be used with the jig, may be an important consideration. If no other factor than cost of production is involved, and it is found that the total cost of the jigged work will come very near that of the lot of articles when made without a jig, and no further order is in sight, it is pretty safe to abandon the jig idea; for it is apt to partake very much of the nature of an experiment, and the odds should be decidedly favorable to warrant the risk.

The second reason—the duplication of pieces—has a somewhat different foundation— though cost enters here also, as will be seen later. Suppose the part to be made is subject to wear or breakage, as in agricultural and textile machinery, guns, bicycles, etc. We know, for instance, the strong disinclination anyone has for buying a wheel, the makers of which have gone out of business. It is at once recognized that repair parts cannot be bought from stock dealers, but must be made at excessive cost and delay. So we have before us the importance to manufacturers that the buying public shall have confidence in the interchangeability of parts in order that sales may be made at all upon the open market. It is a fact that where this reason holds good, there is also the reason that costs will be lessened, because production of large numbers of parts is taken for granted. And in considering whether or not a jig shall be made, this combination of reasons militates strongly for the jig. There is also another equally important reason for jigs, based on costs and interchangeability—it is that, in

* MACHINERY, October, 1902; November, 1906; December, 1906, and January, 1907.

fitting and assembling, those parts which are exactly alike require a minimum amount of labor when putting in place. This, perhaps, one may, without danger of exaggeration, say is in most cases in the machine building business the chief consideration.

In the third place, accuracy is often attained only by the use of jigs. There are certain classes of work which could not be finished at all within the limits of accuracy demanded, if jigs of some sort were not used.

It will therefore be seen that the determination of whether a jig shall be made may rest upon a number of questions which often demand great care and practical experience to solve in the way best meeting the requirements of the case.

Drill Jigs

Drill jigs are used for drilling holes which must be accurately located, both in relation to each other and to certain working surfaces and points; the location of the holes is governed by holes in the jig through which the drill passes. The drill must fit the hole in the jig to insure accuracy of location. When the jig is to be used in drilling many holes, the steel around the holes is hardened to prevent wear. If extreme accuracy is essential, or if the jig is to be used as a permanent equipment, bushings, made of steel and hardened, are used to guide the drills.

General Considerations in Designing Jigs

The design of a jig should depend altogether on the character of the work to be done, the number of pieces to be drilled, and the degree of accuracy ncessary in order that pieces drilled may answer the purpose for which they are intended. When jigs are to be turned over and moved around on the drill press table they should be designed to insure case and comfort to the operator when handling, and should be made as light as is consistent with the strength and stiffness necessary. Yet, we should never attempt to save a few ounces of iron, and thereby render the jig unfit for the purpose we intend to use it for. The designer should see that the jig is planned so that work may be easily and quickly placed in and taken out, and that it can be easily and accurately located in order to prevent eventual mistakes. As it is necessary to fasten work in the jig in order that it may maintain its correct position, fastening devices are used; these should allow rapid manipulation, and yet hold the work securely to prevent a change of location. Yet, while it is necessary to hold work securely, we should not use fastening devices which spring the work, or the holes will be not only improperly located, but they will not be true with the working surfaces or with each other. When finishing the surfaces of drill jigs and similar devices used in machine shops, the character of the finish depends entirely on the custom in the shop, for while in some shops it is customary to finish these tools very nicely, removing every scratch, and producing highly finished surfaces, in other shops it is not required, neither is it allowed, as it is considered a waste of time and an unnecessary item of cost.

Limits of Accuracy

When making drill jigs we must discriminate between measurements that must be *exact*, and those not requiring extreme accuracy; it is not considered good practice, and it shows poor judgment, to spend the amount of time necessary to locate a hole within a limit of variation of 0.001 inch or even closer, if a variation of 1/64 inch is insignificant. But if the holes must be located *exact* as to measurements, it is necessary to work as accurately as possible, and time cannot be considered a factor, provided a man improves every minute. Yet the fact that extreme accuracy must be observed does not warrant a jigmaker *wasting time.*

Before starting to work on tools of this character, the workman should first carefully look over his drawing, making himself thoroughly familiar with the construction, and making sure that the measurements given are, seemingly, correct; if in doubt about anything, consult the foreman, or the draftsman—according to the custom in the shop—in order that every detail may be thoroughly understood, or that any mistake made in the drawing may be rectified.

Many times one draftsman is puzzled to understand a drawing made by an equally good man, especially so if the work is foreign to him; and a shop man, who may not be very well versed in reading drawings—yet be an excellent workman—may easily get puzzled when he attempts to read a drawing of work he is not familiar with. Inquiries and proper explanations are therefore in place, and there should be no hesitation about asking questions, nor any reluctance about replying to them.

Provisions for Chips and Burrs

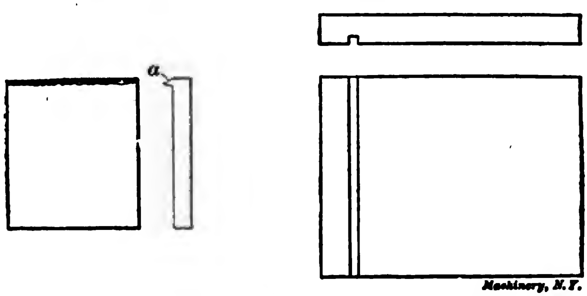
It is necessary when designing tools of any character, whether they be cutting tools or fixtures for holding work while machined, to make provision for the chips. These are liable to get into drill jigs, and despite ordinary care, get under the work or between it and the locating points. In order to do away, so far as possible, with this tendency, it is advisable to cut away as much of the seating surface as can be spared, and to locate stops away from the seating surface, if possible. The seating surface should be smooth enough so that chips will not adhere to it, and so that waste will not stick to it, but it should not be a polished surface, as we would in all probability get it out of true, if we attempted to polish it. If chips are allowed to get under the work it will not be drilled true; that is, the holes will not be at the proper angle with the working surface, and consequently the piece will be unfit for most purposes.

Many operations of machining are almost sure to throw a burr on one side of the piece, and in shops where quantities of work of the same kind are machined, many employes are kept busy removing these burrs in order that they may not interfere with the proper seating of the pieces during the succeeding operations. While the operation of removing the burr on a single piece of work may not incur great cost, yet when thousands of pieces are machined each day, the aggregate cost constitutes quite an item of expense, and the successful manager

is he who so far as possible eliminates the small items of expense, knowing that many small items of expense amount to a large item in the aggregate. Not only is the operation of burring expensive, but as the class of help usually employed to do this work is unskilled, surfaces are many times left in a condition anything but satisfactory. As a consequence, the surfaces of jigs, milling machine fixtures, etc., are many times cut away to receive these burrs, thus doing away with the necessity of burring, as it many times happens that subsequent operations remove the burrs. In Fig. 1 is shown a piece of work having a burr thrown up at *a*, while Fig. 2 represents a surface cut away to receive the burr.

Factors Determining the Advisability of Using Jigs

When we wish to drill two holes a given distance apart, the location of the holes is obtained by means of a pair of dividers set to a scale. The location is obtained and prick punched, after which the holes are drilled. This method answers nicely when one piece is to be drilled, and precise measurements need not be observed. If it is necessary to drill ten thousand pieces, then this becomes a costly method, and the work can be done more cheaply if a jig is made to hold the pieces. The jig must, of course, have holes the size of the drill, which are properly located. By the use of the jig, the cost of drilling is but a fraction of what it would be if the holes were located by dividers, and the surface prick punched as described. As we have already said, the first factor which must be considered is the cost of the jig. If the cost of the jig, plus the cost of drilling, would exceed the cost if the pieces were first prick punched and drilled as formerly described, then the making of the jig would not be considered unless a greater degree of accuracy was necessary than would be liable to be the result of the method mentioned. When a jig is to become a permanent part of the equipment of a shop, its first cost is not so much a matter of consideration as when only a limited number of pieces are to be drilled. Yet no unnecessary expense should ever be allowed.

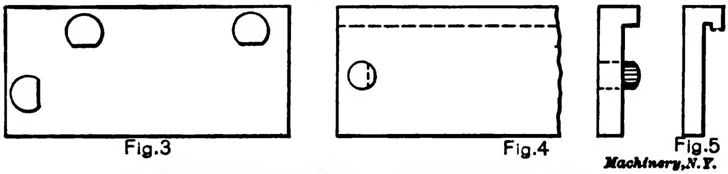


Figs. 1 and 2. Work with Burr, and Grooved Part of Jig to Correspond

Means for Locating Work in Jigs

Many times when only two pieces are to be drilled which must be exactly alike as regards location of holes, it is cheaper to make a

simple jig than to attempt to drill them by any of the methods commonly used in machine shops. In such a case the jig may be made from a piece of cast iron or other material which may happen to be on hand, the holes being carefully laid off and drilled. This jig makes it possible to drill the holes in both pieces exactly alike as to location. When using a jig of this description it is possible to locate the holes near enough for most work by ordinary measurement. If many pieces



Figs. 3, 4 and 5. Means for Locating Work in Jigs

were to be drilled, it would be necessary to provide locating points, so that the pieces could be placed in the jig, and the essential surfaces brought against these. The means of locating may be pins, as shown in Fig. 3, or a shoulder and a pin, as in Fig. 4. If pins are used, they should be so located that the bearing surfaces may be worked flat, as shown, to prevent wear, and also to do away with a tendency to press into the surfaces of the work. If flat shoulders are used they should be cut away, or relieved, at corners, as shown in Fig. 5, to do away, so far as possible, with the liability of dirt or chips getting between them and the work. Then, again, if the working edges of the pieces of work are not exactly true, it would be impossible to properly locate by pressing them against true locating surfaces which extend the whole length.

When work is of irregular contour that could not be properly located by bringing it against two locating surfaces, it is possible to provide a locating device which bears against all the surfaces, as shown in Fig.

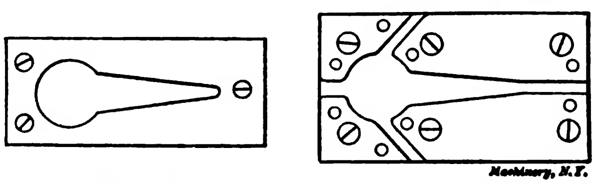


Fig. 6. Method of Locating Work in Jigs

6. This method, however, is hardly to be advocated for most work, as it necessitates exactness of measurement and shape on all the bearing surfaces, as well as on the pieces to be worked upon. Then, again, the shape makes it extremely difficult to clean, and a chip under any portion of the work will cause it to stand at an angle with the seating surface of the jig.

Clamping Devices

It is necessary to hold the work solidly in the jig without any chance of its changing its location. Should the location change after one or

more holes are drilled, and before all are drilled, it would cause a variation that would in all probability spoil the piece of work. When but a few pieces are to be drilled with a jig it is not generally considered advisable to make jigs with fastening devices, the work being held in place with a clamp, as shown in Fig. 7. In order to do away with any possibility of change of location, a pin is forced through the jig hole and the hole in the work after drilling the first hole. If many holes are to be drilled in a piece it is advisable to have two pins. After drilling a hole in one end of the piece, force in a pin; then drill a hole in the opposite end, and place a pin in this hole, as shown in Fig. 8. The pins in opposite ends of the piece will prevent its slipping when the rest of the holes are drilled. Many different forms of fastening devices are provided, the design depending on the class of work. One of the most positive methods consists of a screw which passes through a stud or some elevation on the jig, and presses

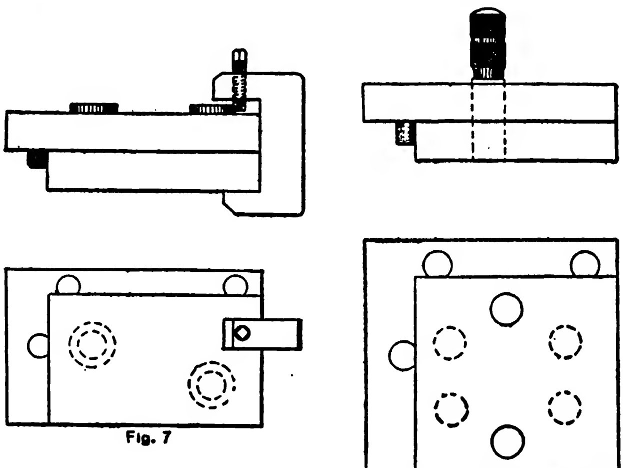


Fig. 7

Fig. 8 *Machinery, N.Y.*

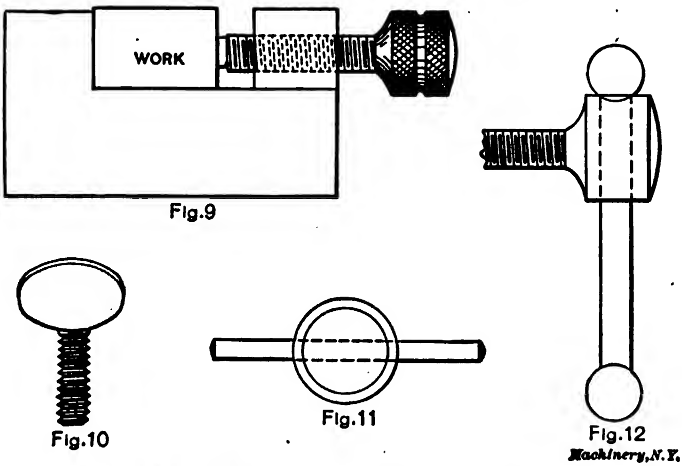
Figs. 7 and 8. Means for Holding Work in Drill Jigs

against the work, forcing it against the locating points, or stops, as they are called. The screw may have a knurled head, as shown in Fig. 9, or a thumb-screw may be used, Fig. 10. Sometimes it is necessary to exert greater pressure than can be applied by means of a screw of the ordinary form. Then, it is possible to make a screw with a round head, drill a hole through it, and through this hole pass a piece of wire as shown in Fig. 11. By this screw, sufficient pressure can be applied. When it is necessary to exert a greater amount of power than would be possible by the use of a pin of the length shown in Fig. 11, one may be used that will slide freely in a hole in the head of the screw. A ball placed on each end prevents its falling out. By getting the full length of the pin on one side of the screw-head, as shown in Fig. 12, a much greater amount of power is obtained. At times the stud which supports the screw may interfere with the plac-

ing of the work in, or the removal of the work from the jig, or it might be necessary to turn the screw for a considerable distance each time the work was placed in or taken out of the jig. In such cases a stud could be provided that could be removed from the jig when the screw was relieved of its tension against the piece of work. Such a stud is shown in Fig. 13.

Clamping Work by Cams or Eccentrics

A common method of fastening work is by means of a cam of suitable form. Cams of the ordinary design are not as powerful as the screw, but they have the advantage of being more quickly operated,



Figs. 9 to 12. Means for Clamping Work in Drill Jigs

and in the case of light work where but little strength is required, they answer the purpose much better. The designer should bear in mind that a few seconds' time saved on each piece of work amounts to a large saving in a day when a number of hundred pieces are placed in and taken out of a jig; and in these days of competition every means of saving time consistent with quality of work should be considered. When the work bears against two points—one on the side and one on the end—the cam should be designed so that its travel against the work will force it against both, rather than away from one. Fig. 14 shows a piece of work held by a cam which, by means of the handle, forces the work inward and in the direction of the arrow, thus holding it against the locating pins *a a* and the end stop *b*. In order to get as much pressure as possible with a cam, it is necessary to have the portion that bears against the work when it is against the locating surfaces nearly concentric with the screw hole. This being the case, it is obvious that the pieces must be very nearly of one size, while in the case of a screw binder any amount of variation may be taken care of. Thus it will be seen that a screw may be used where a cam would not answer. However, it is advisable to use a cam in prefer-

ence to a screw when possible, but at times the piece of work may be subjected to repeated jars which would tend to turn a cam, thus loosening the work. In such cases a screw is preferable. If a cam would be in the way when putting in or taking out work, it may be made removable, as shown in Fig. 15. At times a tapered piece of steel in the form of a wedge may be used to hold work, as shown in Fig. 16.

Simple Forms of Drill Jigs

When many pieces are to be drilled in a jig made in the simple form shown in Fig. 17, the drill wears the walls of the holes, enlarging

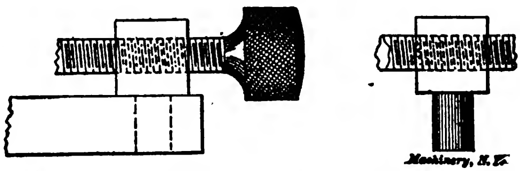


Fig. 13. Clamp Screw Mounted in Removable Stud

them sufficiently to render accuracy out of the question. Where jigs are to be used enough to cause this condition, the stock around the walls of the hole may be hardened, if the jig is made from a steel that will harden. If made from machinery steel, the stock may be case-hardened sufficiently to drill a large number of pieces without the

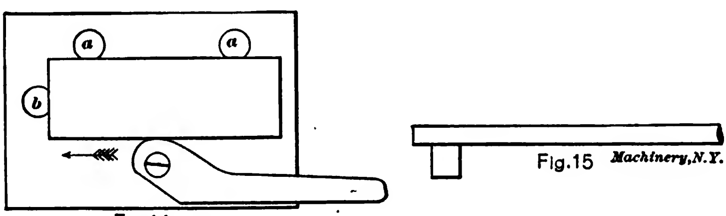


Fig.14

Figs. 14 and 15. Eccentric Clamp for Simple Drill Jigs

walls wearing appreciably. This, however, would not answer when accuracy is essential, as the process of hardening would have a tendency to change the location of the holes.

Guide Bushings

When the jig is to be used for permanent equipment, or where many holes are to be drilled, it is customary to provide bushings—guides—made of tool steel and hardened. These are ground to size after hardening, and being concentric, may be replaced, when worn, by new ones of the proper size. It is the common practice to make bushings for drill jigs on the same general lines as shown in Fig. 18, the upper end being rounded to allow the drill to enter the hole readily. A head is provided, resting on the surface of the jig; the portion that enters the hole in the jig is straight, and is ground to a size that insures its remaining securely in place when in use.

If the hole is sufficiently large to admit a grinding wheel, it is

ground to size after hardening. In such cases it is, of course, necessary to leave the hole a trifle small—0.004 inch—until it is ground. If the hole is not large enough to allow of grinding, or if there is no means at hand for internal grinding, the hole may be lapped to size by means of a copper lap, using emery or other abrasive material, mixed with oil. When the hole is to be lapped rather than ground,

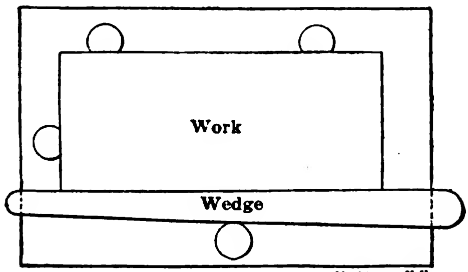


Fig. 16. Wedge Acting as Clamp in Drill Jig

leave a smaller amount of stock to be removed by the operation, say 0.001 inch or 0.0015 inch. After grinding or lapping the hole to size, place the bushing on a mandrel and grind the outside until it is a pressing fit in the hole. While on the mandrel, be sure to grind the

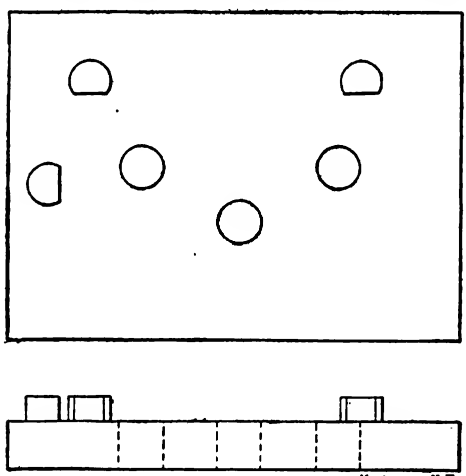
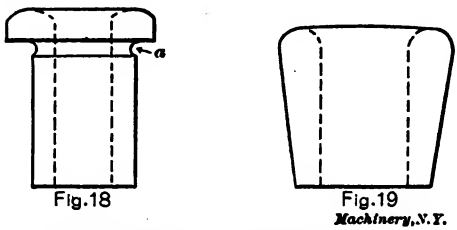


Fig. 17. Simple Form of Drill Jig without Bushings

under portion of the head, *a*, Fig. 18, to insure its being true with the body. Before starting to grind the outside of the bushing, test the mandrel for truth. This should be done *after* placing the bushing on it rather than before.

It is the custom in a few shops to make the outer portion of bushings tapered, as shown in Fig. 19. Unless there is a sufficient reason for so doing, this is to be avoided, as the operation of making a tapered

hole, unless it is bored on the taper with an inside turning tool, is not likely to produce a hole, the axis of which is at the desired angle to the surface of the jig. The outer portion of the bushing can easily be ground to the desired taper, but there is the liability of a particle



Figs. 18 and 19. Bushings for Drill Jigs

of dust getting in the hole when placing the bushing in the jig. A tapered bushing, in order to get the proper taper, necessarily costs a great deal more than a straight one, and cannot answer the purpose any better, and probably not as well.

Types of Drill Jigs

The shape and style of the jig must depend on the character of the work, the number of pieces to be drilled, and the degree of accuracy essential. It may be that a simple slab jig of the design shown in Fig. 20 will answer the purpose; if so, it would be folly to make a more expensive tool. If we are to drill a piece of work of the design shown to the left in Fig. 21, and but one hole is to be drilled in each piece, then a jig made in the form of an angle iron, as shown to the

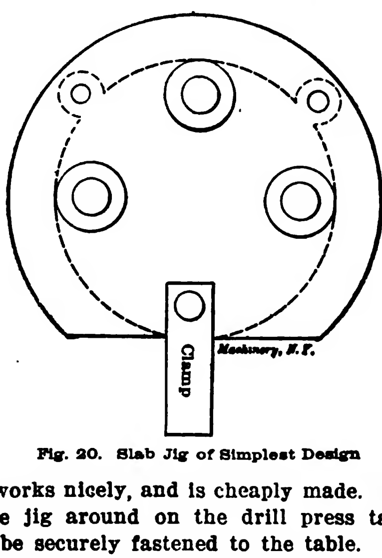


Fig. 20. Slab Jig of Simplest Design

right in Fig. 21, works nicely, and is cheaply made. As it is not necessary to move the jig around on the drill press table it may, after locating exactly, be securely fastened to the table. In designing such a jig, it is advisable, when possible, to have the work on the side

of the upright shown in Fig. 21, rather than on the opposite side, as that does away with any tendency of the jig to tip when pressure is applied in the operation of drilling.

Leaf Drill Jigs

For many kinds of work a jig provided with a leaf, as shown in Fig. 22, gives best results, as the leaf may be raised, and the work removed, and any dirt cleaned from the working surfaces. After placing the piece to be drilled in the jig, the leaf is closed. As the bushings are in the leaf, it is apparent that it must always occupy the same relative position to the work for the different pieces, or they will not be duplicates; consequently, the fulcrum pin, *a*, must be a perfect fit in the hole in the leaf, and a locating pin *b* is provided to prevent any tendency of the leaf to move from the action of the drill when cutting. Jigs provided with such a pin show less tendency to wear in the joint. The leaf should not close down onto the work, but

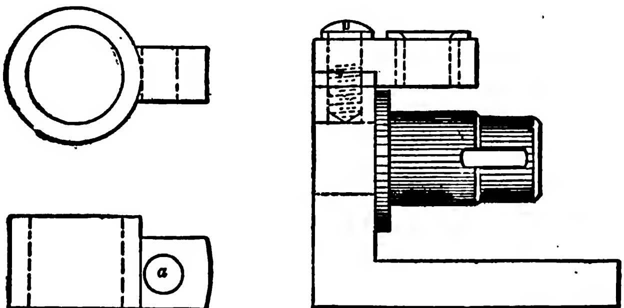


Fig. 21. Piece to be Drilled, and Jig Used for this Work

onto a shoulder on pin *b*, as shown, there being a space between the work and the jig leaf.

While the above is true for most work, a jig for drilling round pieces may be designed as shown in Fig. 23, the holding device being two V-shaped blocks, one located on the lower portion of the jig, while the other is on the leaf, as shown. In the case of a jig of this pattern, the work is securely held by binding the cylindrical piece by pressing the handles of the jig together.

Jigs Provided with Feet or Legs

When jigs are to be moved around on the table of the drill press, as is the case where several holes are to be drilled, feet or legs are generally provided, as shown in Fig. 22. In order that the legs may not wear, it is customary to harden them. The legs are hardened before they are placed in the jig, and are ground and lapped true while in the jig. As the only wear is on the ends, or where they come in contact with the drill press table, it is customary to harden only the ends which rest on the table. In most shops jig legs are made from tool steel, although a good grade of open-hearth steel containing sufficient carbon to insure its hardening answers as well for most purposes. But

as few shops carry such steel in stock, crucible tool steel is generally used. The ends of the legs should be ground true with the seating surface—that is, where the work rests—of the jig. To accomplish this a surface grinder should be used. As the operation of grinding leaves a number of projections on the surface ground, and as these ridges or projections would wear away as the legs were moved back and forth

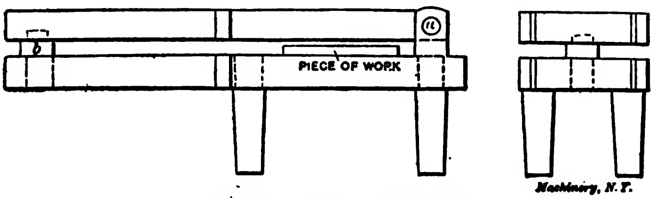


Fig. 22. Jig with Pivoted Leaf

on the drill press table, it is advisable to remove them by lapping on a flat lap, thus producing a perfectly smooth, true surface. In this way we reduce the wear to a minimum.

For certain classes of jigs the legs may be short, not more than ½ inch long; but for jigs of the style shown in Fig. 22, where the tool is held in the hand, it is necessary to make the legs longer to

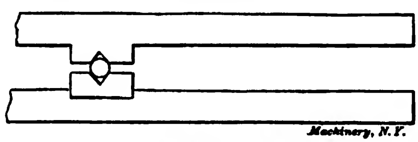


Fig. 23. Part of Jig with Pivoted Leaf, Showing Method of Holding Round Work

keep the fingers from coming in contact with the chips on the drill press table. The legs should be located so as to do away with any tendency of the jig to tip up when the work is being drilled.

Relation Between Accuracy of Jigs and Accuracy of Machines on which They are Used

While it is necessary to observe extreme care in designing drill jigs to prevent any tendency of the jig to tip, and to have the legs ground and lapped on a true plane, it is just as necessary that the drill press table should be perfectly at right angles to the spindle, and that it should be true and flat. Otherwise, the holes will not be at the desired angle with the working surface of the work.

In shops where interchangeable work is produced, or where the work must in all respects be machined correctly, the condition of the various machines is closely watched, and especially such parts of the machines as affect the accuracy of the finished product. Drill press tables are planed over when out of true, or are lined up to insure their being at right angles to the spindles of the drill press. This may be done by placing a bent wire in the drill chuck, the wire being bent so that it will describe as large a circle as possible, and yet be free to swing. The end of the wire is bent so that the point will come in

contact with the table. By loosening the screws holding the table, and inserting "shims," it may be trued as desired.

Locating the Holes for the Drill Bushings

When making jigs, the part of the work that calls for the best workmanship is locating the holes for the drill bushings. The methods employed differ, but should depend on the character of the work. Where accuracy is not essential, it is the custom many times to take a piece of work that is right, or, rather, one where the holes are drilled near enough right, place this in the jig and transfer the holes into the jig. As it is necessary to leave the bushing holes in the jig considerably larger than the holes in the work in order to have sufficient stock

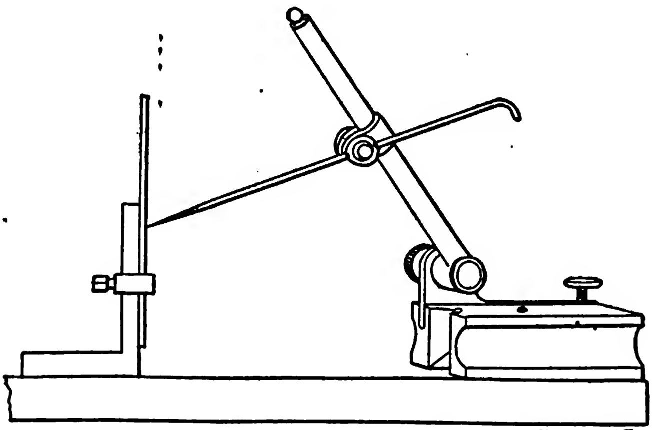


Fig. 24. Method of Taking Vertical Measurements

around the holes in the bushing, those in the jig may be enlarged by means of a counterbore, the pilot of which fits nicely in the transferred holes, and with a body the size of the desired hole. When this method does not insure desired accuracy, several other methods may be employed.

Making a Jig from a Sample Piece or Model

If a model of the work to be done is at hand, a jig, as shown in Fig. 22, may be made in the following way: The leaf is raised and the model put in place. The jig is fastened to the face-plate of the lathe, the leaf still being raised. By means of a center indicator the jig is located so that one hole of the model runs true; the leaf is then closed and the hole is drilled through it, and then bored with a boring tool to the desired size. Never ream a bushing hole in a jig, or any similar hole in any piece of work, where the finished hole must be exactly located, as a reamer is liable to run out somewhat and thus affect the accuracy of the work. A reamer, if properly made and used, will produce a round, true hole, accurate as to size, and is a valuable tool for many purposes, and holes of a uniform size may be produced. But on account of the stock being uneven in texture, or on account of

blow holes in castings, a reamer is liable to alter its course and so change the location of the hole. While for many purposes this slight alteration of location might be of no account, yet for work where accuracy is essential, it is out of the question.

After drilling and boring the first hole, the jig may be moved on the face-plate, and the other holes produced. It is abvious that in order to produce holes that will be at right angles to the base of the jig, the face-plate of the lathe must run true, and should be tested each time it is used for any work where accuracy must be observed.

Method of Locating Holes When Accuracy is not Essential

Where there is no model, and it is not considered advisable to make working models of the various parts, the location of the bushing holes may be obtained by laying out the various points on the jigs. In such cases a drawing is usually furnished, and the dimensions on same are transferred to the face of the jig. If it is not necessary to have the holes exact as to measurements, the laying out may be done with a surface gage, the point of the needle being set to a scale. The scale

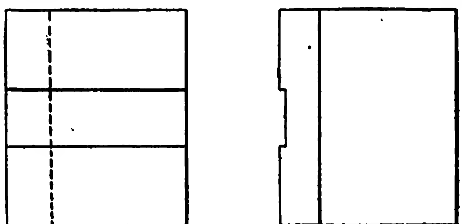


Fig. 25. Angle Iron with Groove for Scale

may be clamped against an angle iron, as shown in Fig. 24, or an angle iron may have a groove of the width of the scale cut across its face at right angles to the base, as shown in Fig. 25. The scale should be a good fit in the groove, so fitted that it will stay securely at any point from frictional contact with the sides of the slot, or a spring may be so arranged as to insure the proper tension.

Method Assuring a Fair Degree of Accuracy

Where greater accuracy is essential, the working points should be obtained by means of a height gage, as shown in Fig. 26. By means of such a tool the measurements may be fairly accurate, as the vernier scale allows of readings to one-thousandth inch. When the lines have been scribed at the proper locations they are prick punched. In order to prick punch exactly at the intersection of lines the operator must wear a powerful eye-glass, and use a carefully pointed punch, ground to an angle of 60 degrees. If the punch marks are made very light at first, the exact location may be observed nicely. The punch marks should not be deep, as there is a liability of alteration of location if the punch is struck with heavy blows. After the various points have been located and punched, the jig may be clamped to the face-plate of the lathe, and the bushing holes carefully drilled and bored to size.

At times jigs are made of such size and design that it seems wise to core the bushing holes. In such cases it is necessary, in order that we may lay out the location of the centers of desired holes, to press a piece of sheet steel or sheet brass into the cored hole, as shown in Fig. 27, and locate the center on this piece. When the holes are properly located for machining, the sheet metal may be removed and the holes finished to the desired size. If an error of 0.001 or 0.002 inch is not permissible, the method described above should not be employed.

Method Employed for Highest Degree of Accuracy

Where extreme accuracy is essential we must locate round pieces of steel on the face of our work. These pieces of steel are called buttons and are of exact size and perfectly round. To do away with any possibility of their becoming bruised in any way, they are hardened and carefully ground to size. The buttons are attached to the work by means of machine screws, as shown in Fig. 28, the holes in the buttons being larger than the screws used; this difference in size allows us to move the button until it is accurately located. The diameter of the buttons should be some standard size, exactly divisible by two, because, in making our computations we only consider the distance from the center of the button to its circumference, that is, the radius.

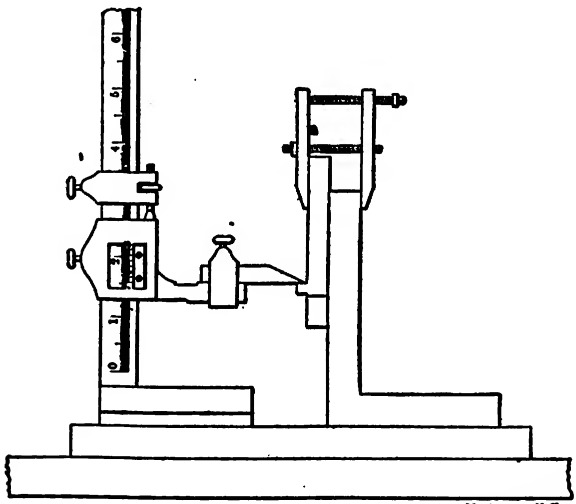


Fig. 26. Taking Vertical Measurements by Means of Height Gage

When we start to lay out the centers for the bushing holes we first determine our working surface, then lay out on the face of the jig, by means of a surface gage, as described in a previous operation, the centers of the holes to be produced. We then drill and tap screw holes to receive the screws to be used in holding the buttons to the jig. When we have prick punched the surface, and before drilling the holes, we scribe by means of dividers a circle the size of the button on

the face of the jig with the punch mark as center. This enables us to approximately locate the button. If the hole to be produced has its center 2 inches from the base *a* and 4 inches from vertical side *b*, Fig. 29, we would locate the button—provided it was ½ inch diameter—1¾ inches from *a*, and 3¾ inches from *b*. This can be done accurately by the use of a vernier caliper, or we can lay the jig on the side *b*, and by means of a length gage, or a piece of wire filed to the right length, accurately determine the distance from *b* to the button. The jig is then placed on the base *a* and the other dimension obtained in the same manner. The buttons may be located more easily by the use of a vernier height gage, if one is at hand.

If there are to be several bushings on the face of a jig, a button may be accurately located where each hole is to be. The jig may be clamped to the face-plate of the lathe so that one button is located to run exactly true. This is done by means of a lathe indicator. When

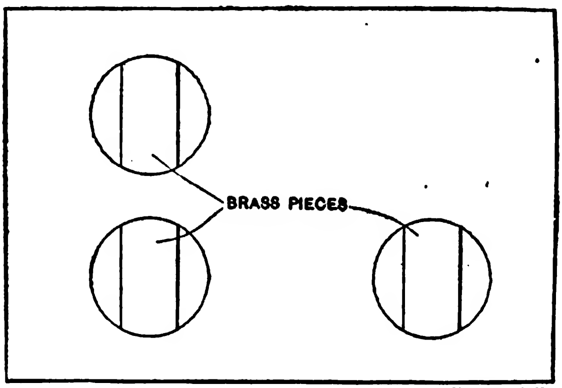


Fig. 27. Cored Holes with Inserted Brass Pieces for Centers

the jig has been so located that the button runs perfectly true, the button may be removed and the hole enlarged by means of a drill, so that a boring tool can be used to bore it to the proper diameter.

Locating the Holes on the Milling Machine

In some shops it is not considered advisable to locate a button at the desired position of each bushing hole. One button is located and the jig is fastened to the table of a milling machine having a corrected screw for each adjustment. Then, after one hole is accurately located and bored, it is a comparatively easy matter, by means of the graduated dials, to obtain the other locations; however, this method should never be used unless the machine has all its movements governed by "corrected" screws, as the screws ordinarily sent out on milling machines are not correct as to pitch, and if used, serious defects in measurements will result. Many tool-makers, therefore, prefer using a vernier scale and vernier attached to the knee and table of the milling machine, for accurate work, as they are then independent of the inaccuracies that may be present in the feed-screw.

Fig. 30 shows a jig clamped to an angle iron on the table of the milling machine. The angle iron is located exactly in line with the travel of the table, and the jig fastened to it. The button *D*, which has previously been accurately located, serves as a starting point, and the jig must be located so that the button is exactly in line with the spindle of the machine. This is accomplished by moving the table

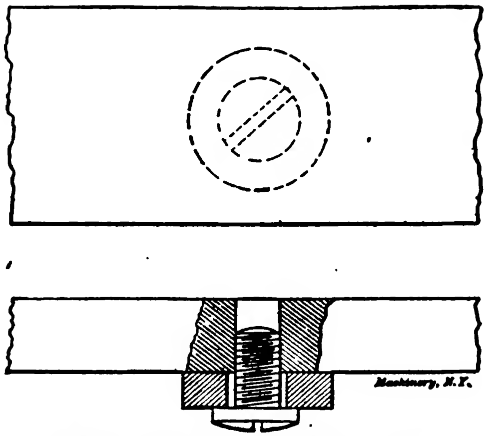


Fig. 28. Buttons for Locating Holes in Jigs

until the sleeve *A* on the arbor *B* will just slide over the button *D*. The hole in *A* must be a nice sliding fit on the arbor *B* and also on the button *D*. In order to insure accuracy, the arbor *B* must be turned to size in the spindle just as it is to be used; or, if a portable grinder is at hand, the arbor may be fitted to the spindle hole or to the collet, as the case may be; the portion which receives the sleeve *A* may be

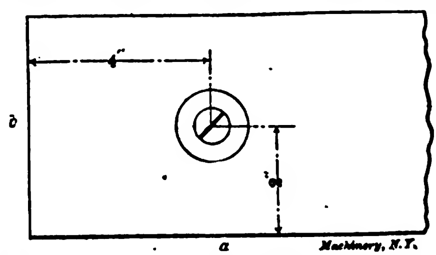


Fig. 29. Locating a Hole by Means of a Button

left a trifle large, and may be ground to size in place on the machine. The portable grinder is located on the table of the machine.

After the jig has been accurately located so that the button *D* allows the sleeve *A* to slide over it, the arbor *B* may be removed from the spindle, and a drill be employed to increase the size of the tapped screw hole that received the screw used in fastening the button. Best results follow if a straight-fluted drill, as shown in Fig. 31, is used. The drill should not project from the chuck or collet any further than necessary,

thus insuring the greatest rigidity possible. After drilling, a boring tool of the form shown in Fig. 32 may be substituted for the drill, and the hole bored to size. The machine may now be moved to position for the next bushing hole by observing the dimensions given. The operator should bear in mind that the screw used in getting the spac-

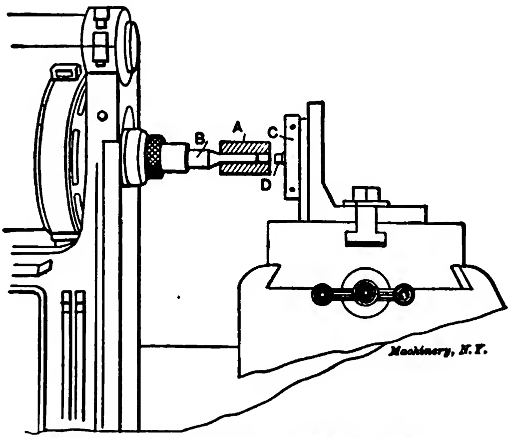
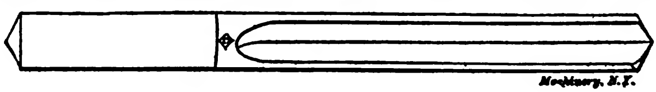
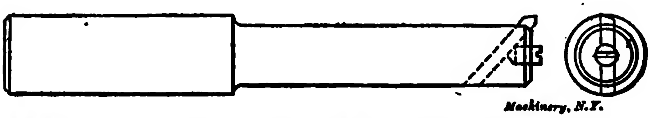


Fig. 30. Locating Holes in the Milling Machine

ings must be turned in the same direction at all times, otherwise the backlash will render accuracy out of the question.

While the foregoing relates to plain jigs, the same principles apply to those of more complicated design. In the next chapter attention





Figs. 31 and 32. Straight-Fluted Drill and Inserted Cutter Boring Tool

is given to a different and original method of locating the holes in jigs, using the drill press for this work exclusively, and Chapter III is devoted to examples of actual designs of drill jigs, showing how the elementary principles outlined above are employed in the practice of the machine shop.

CHAPTER II

DRILLING JIG PLATES*

A description of the following method of drilling jig plates was contributed to the columns of MACHINERY, October, 1902, by Mr. J. R. Gordon. The method being radically different from any of those in common use, it has been deemed proper to mention this method in connection with other methods for locating the holes in jigs already referred to.

In the case in question, a great many jigs were to be made, and the positions of the drill bushings were to be accurate within 0.001 inch. The procedure was as follows: The regular work-table from an ordinary sensitive drill press of the usual pattern was removed, and substituted by one of larger dimensions, as this was called for by the size of the jig plates to be made.

This table was first planed on the face and edges, and the stem, by which it is held in the bracket on the column of the press, was turned to fit snugly the hole in the bracket. After planing and turning the table, a series of holes was drilled, as shown in Fig. 34, and they were tapped to receive a No. 14-20 screw. Two parallel pieces *C* and *D*, Fig. 34, having straight edges and a thickness of 3/8 of an inch, were made. These may be clamped to the table in such a position as may be desired or the work determine, the series of holes permitting any adjustment within the range of the table. In order to make more room between the spindle and the column of the drill press, the spindle head was blocked out, the block having a projecting lug, as shown at *A*, Fig. 33, to which a bracket, *F*, was fastened to carry the bushing, *B*. This bushing is fastened by a screw and can readily be removed and others inserted, having various sizes of holes, if found desirable. These preparations were all that were necessary with the exception of the gages that will be described in the operation of the method for spacing, which is as follows:

The plate to be drilled had a number of holes spaced as shown in Fig. 34, and before drilling them they were marked as Nos. 1, 2, 3, etc., No. 1, as will be seen, being the upper left-hand hole. Its location with reference to either end or sides of the plates did not require to be very exact; but other plates may need to have holes placed at some definite distance from the edges or ends, so it may be assumed that the distance is 6 inches from the edge, *G*, and 8 inches from the end, *H*.

With these distances given, make two gages, using vernier or micrometer calipers for standard, and make them 6 1/8 and 8 1/8 inches long, respectively. Remove the bushing, *B*, Fig. 33, and in its place insert a plug having a diameter of 1/4 inch.

* MACHINERY, October, 1902.

Resting the 6⅛ gage on the table, and with one end touching the plug, the parallel piece, *C*, Fig. 34, is brought to just touch the other end of the gage and is then clamped to the table. This is not very difficult if one end of the parallel is left free and the other end is clamped tight enough to permit the free end to move somewhat stiffly. After locating and clamping the parallel, *C*, the other parallel

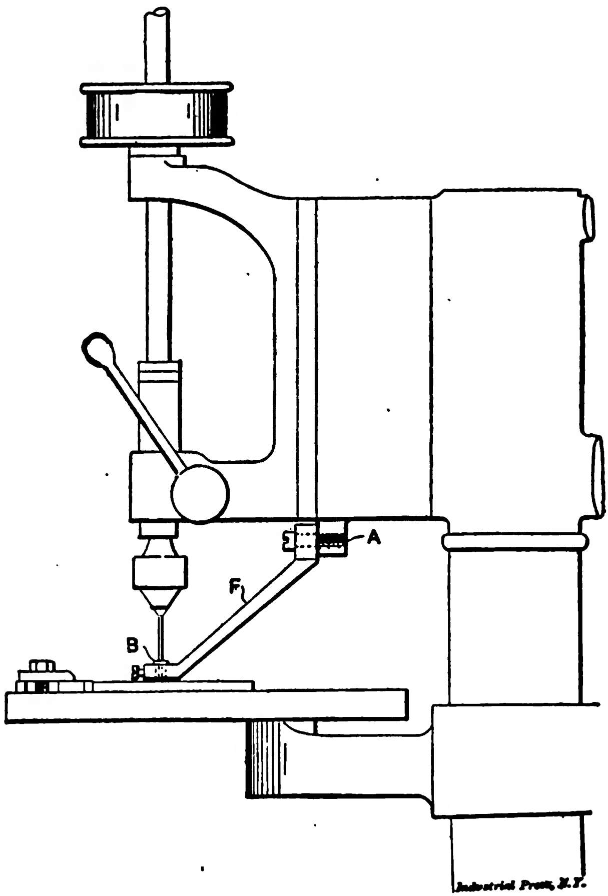


Fig. 33. Drill Press arranged for Drilling Jig Plates

is clamped in position, but it must be placed square with the first parallel. This is more difficult than in the first case, but is not at all difficult if one man can be employed to clamp the piece while another holds the square and gage. The reason for making the gages 6⅛ and 8⅛ inches long instead of 5⅞ and 7⅞ inches, respectively, is that it is not desirable to have the edges of the plate touch against the parallels, as chips could get between the two and destroy the accuracy of the measurements; allow the gage to be ¼ inch longer than the distance

required, and fill in the space with ¼ inch diameter gages, as shown in Fig. 34.

For gages over 1 inch in length use flat brass rods or strips about ⅜ inch wide and ⅛ inch thick, and cut them a little longer than the

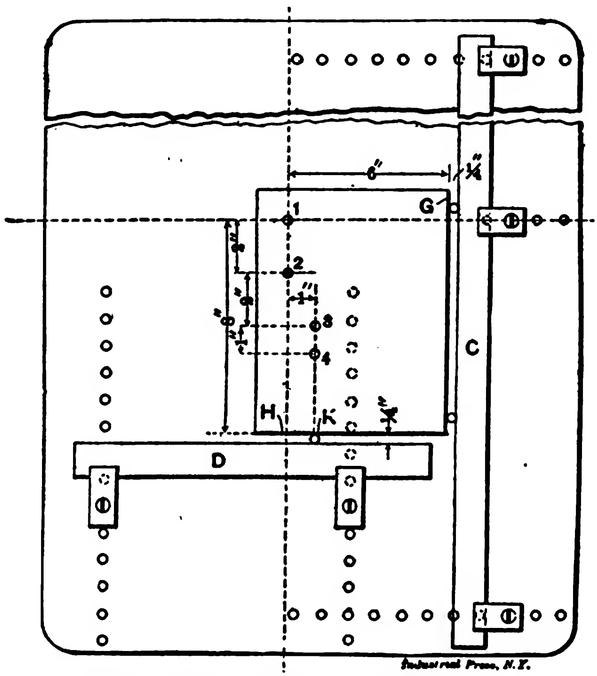


Fig. 34. Plate in Position for Drilling First Hole

finished length. One end is finished square and the other end is rounded as shown in Fig. 35. In making the gage, if too much metal is removed, it is an easy matter to pene the stock out to make up for any reasonable error. The length of the gage is stamped on it, and when the operation is completed it is put away for future use.

Having located the parallels, the plug is removed from the bracket

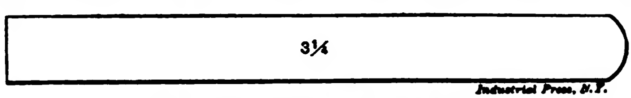


Fig. 35. Type of Gage used when Drilling Jig Plates

and the bushing replaced. The drill should, of course, fit as snugly to the hole in the bushing as it can and run without cutting. The bushing should support the drill to within a distance equal to the diameter of the drill from the plate to be drilled, and care should be taken not to drill through the plate until all the holes have been started. After drilling the first hole, to place the plate for the second hole, distant 2 inches from the first, it is moved along the parallel, *C*,

and a gage 2¼ inches long placed as shown in Fig. 36, and when so placed is ready for drilling. The third hole requires three new gages, since it is 1 inch off the line of the other two holes, as shown in Fig. 37.

For holes which are to be finished 3/16 inch to ¾ inch in diameter, use first a small drill, size No. 52 to No. 30. After the holes are all drilled to this size, then enlarge them, by the use of a series of four lip counterbores, to the required size. Where extreme accuracy is required, in the place of the counterbore, a small boring bar may be substituted and the holes bored to the size desired. One disadvantage of using a boring tool is that it requires a hole in the table equal to the largest hole to be bored out, or that the plate shall be kept clear of the table by blocking up with parallel strips under it.

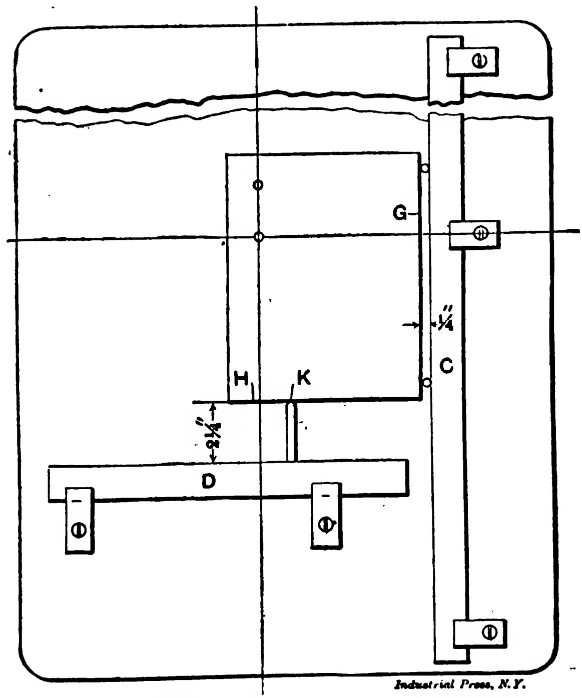


Fig. 36. Plate in Position for Drilling Second Hole

Fig. 38 shows a form of boring tool which will be found very convenient for use on this kind of work. It consists of the shank, *A*, which is fitted to the taper hole in the spindle, and a split holder, *B*, which is pivoted to the shank at *C*, and is locked to it at *D*, the screw at *D* serving to clamp the boring tool, *E*, at one end, while *F* clamps it at the other end. Adjustment is obtained by swinging the holder, the radial slot, *G*, allowing it to have quite a range, and the top screw, *H*, permitting fine adjustment. Split bushings in the holder will allow the use of boring tools of smaller diameter if desired.

This method of locating holes is not limited to the drill press, but may be employed to advantage on the face-plate of a lathe. In this case, the work, as soon as located by the gages, is clamped to the face-plate.

While this method was originated for drilling holes in jig plates, it may be used with equal success for drilling small interchangeable pieces. It is not necessary that the edges, *G* and *H*, be planed at right angles, as the same results will be obtained if the surface, *G*, is planed true and a finished spot provided at *K*, from which point all measurements to the parallel, *D*, are made.

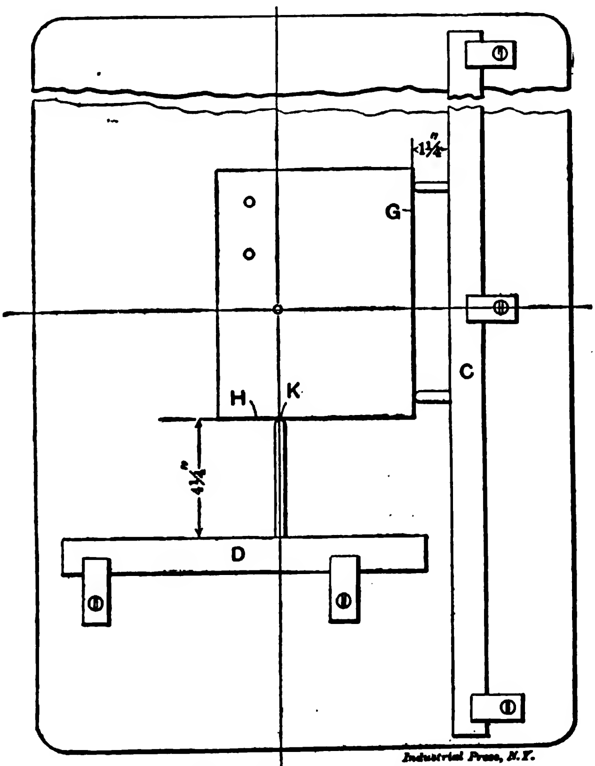


Fig. 37. Plate in Position for Drilling Third Hole

Mr. Gordon claims that this system has certain advantages over the button methods used on the milling machine. In the first place, the feed-screws on nearly all milling machines are not correct, and in some shops the tool equipment is so badly worn as to make the use of the feed-screws out of the question for accurate work.* However accurate a screw on a milling machine is when new, it soon loses its truth under ordinary conditions of machine shop practice, since only a small

* See page 18: Locating the Holes on the Milling Machine.

portion of the screw is used to do most of the work of driving the table. In the second place, Mr. Gordon claims that his method is quicker, the supposition being that the necessary appliances, such as parallels, brackets, bushings, etc., are made and ready for use; and finally, that there is a very small chance for errors, provided that the gages used are marked distinctly.

These assertions, however, called forth considerable comment in the columns of MACHINERY. Mr. Frank E. Shailor, in particular, took issue with Mr. Gordon on account of these assertions and claimed that there were considerable chances for errors. Mr Gordon, however, defended

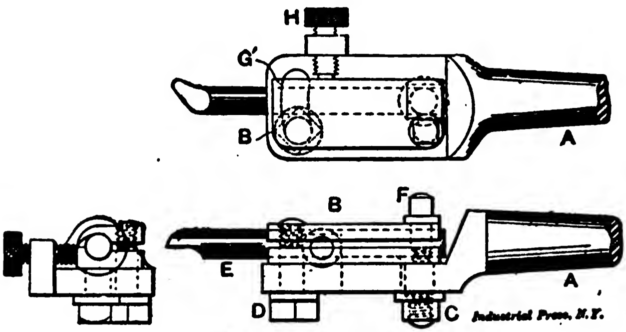


Fig. 38. Boring Tool

his method, pointing out that most of Mr. Shailor's objections were of little consequence, provided proper precautions were taken. Other contributors added their word to the discussion, some siding with Mr. Gordon, and some admitting that the methods used both by Mr. Gordon and Mr. Shailor would, under proper circumstances, be correct to use. It is not possible in this treatise to give place to what was more a personal controversy, than of direct bearing upon the subject of drill jig design. It may, however, be proper to mention that the discussions on this subject appeared in the July, August, September and November, 1904, and the January and February, 1905, issues of MACHINERY.

CHAPTER III

EXAMPLES OF DRILL JIGS

In the following will be given a number of examples of drill jig designs for definite purposes, as employed in various shops in the country. No attempt has been made to show only jigs of which it can be said that the design is perfect or nearly so, but examples have been taken which indicate general practice, and attention has been called to wherein these jigs conform to the principles of drill jigs as treated in Chapter 1, and also to the objections that might be raised against each particular design, if such objections have been considered in

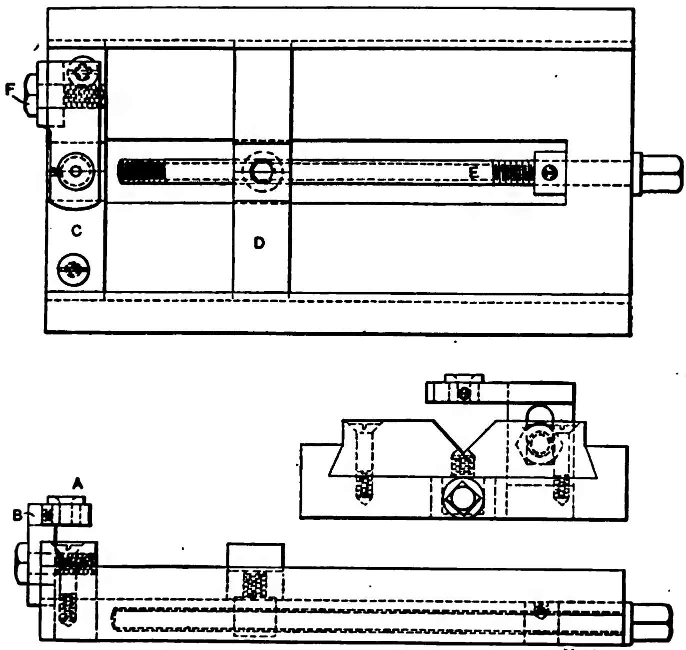


Fig. 39. Jig for Drilling Holes in Studs and Shafts

place. The names of the persons who originally contributed to the columns of MACHINERY the descriptions of the devices shown, have been given in notes at the foot of the pages, together with the month and year when their contribution appeared.

Jigs for Drilling Pin Holes in Shafts

Usually, the simplest kinds of jigs are those intended for drilling a hole through the center of a shaft. They often consist only of a

V-block, in which the work rests, and a cover of the simplest design, containing the guide bushing. Sometimes, however, they are made more universal; the cuts Figs. 39 and 40 show two such designs.

The jig in Fig. 39 is intended for drilling pin holes in comparatively short studs, and will handle a variety of such work with great rapidity. The drill bushing *A* can be removed and bushings with different size holes inserted. The bushing holder *B* can be raised or lowered to suit different diameters of work. The V-block *C* is fixed, while block *D* is adjustable by means of the screw *E* for different lengths of studs. By fastening a strap to the device by screw *F*, and providing this strap with an adjustable screw in line with the V's, studs can be gaged from the end instead of from the shoulder, which, when used for gaging, rests against the sides of either of the V-blocks. The manner in which this jig is used lends itself well to a variety of work of all descriptions.*

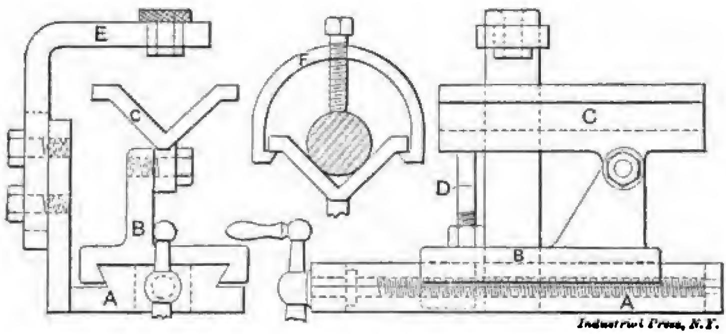


Fig. 40. Jig for Drilling Holes in Shafts

This jig is a simple, yet efficient and characteristic, example of the adjustable type of jig. It will be noticed that the design does not provide for any clamping device for the work to be drilled; this is on account of that in this case the holes to be drilled are so small, compared with the diameter of the shaft or stud, that the stud will stay in place by its own weight, or by pressure of the hand on its upper side, the V-groove aiding materially in keeping the work in position.

The device shown in Fig. 40 is another example of an adjustable jig for this class of drilling. This tool has proved to be of the greatest convenience for drilling shafts, spindles or other round pieces. The base *A* is dovetailed and fitted with a lead-screw, which moves the slide *B* in and out. Upon this slide is mounted the adjustable V-block *C*, which can be tipped at any desired angle for oblique drilling, or set perpendicularly to hold the shafts in position for end drilling. The adjustable stud *D* is placed under the outer end of the block to hold it firmly in any set position. The arm *E* is adjustable up and down, for different sized shafts, and is supplied with a complete set of bushings for use with drills of different diameters. When mortising bars, intended to be used as holders for facers, boring cutters, counterbores

* Paul W. Abbott, August, 1907.

with interchangeable blades, etc., the work is clamped into the V with the clamp *F*, and then, after the first hole has been drilled, the slide is moved along for a distance equal to the diameter of the drill, and the next hole drilled, and so on. By this method any number of holes can be drilled in perfect line, and always through the center of the bar. By the use of a stop clamped across the end of the V-block, the attachment forms a jig which can be used for a great variety of duplicate drilling.*

A jig for drilling cotter-pin holes, which facilitates the operation considerably as compared with the way it is commonly done, is shown in Fig. 41. It consists of two pieces of steel forming a clamp, each piece having a V-groove to receive different diameters of studs. The

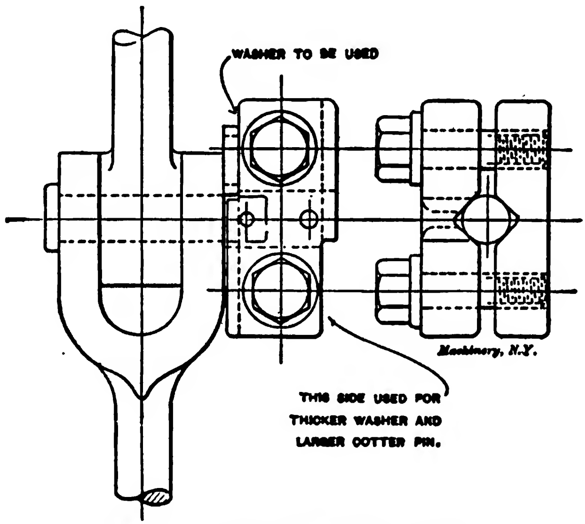


Fig. 41. Jig for Drilling Cotter-pin Holes

upper one contains two holes which correspond with the size of cotter-pins desired. Should more than the two sizes be required, extra top pieces can be used with the same bottom piece. Part of the upper piece is cut away on each side in line with the edge of the holes, which allows the washer to be used to be inserted at the recess, and the jig then clamped in position. By this means no scribing or spotting is necessary and a much better job can be done. Although it is shown so in the cut, it is obvious that the male portion of the joint need not be in position when drilling.

Jigs for Drilling Collars

The jig shown in Fig. 42 has been used with much satisfaction for drilling set-screw holes in collars. The collar *C* is held in position by means of the three locating pins *D*, *D*, *D*, and the swinging clamp *E*. In order to place a collar in position for drilling, the strap is swung

* Roy W. Harris, April, 1903.

to one side about the hand screw *G*. When the collar has been put in place the clamp is swung back, and in doing so, its motion is limited by the pin *F*, which brings it to a stop directly over the collar. At the top of the jig is a bushing *B* through which the drill is guided. When the outside diameter of the collars is likely to vary, the pins *D, D, D*, may be replaced by a central pin, *L*, as shown in the separate view in the cut, and the collar held on this while it is being drilled.*

The jig shown in Fig. 43 is designed for drilling the holes in the center of collars, and the method of drilling, described below, also suggests the value of systematizing the work in using jigs. The collars to be drilled are made of annealed tool steel in sizes varying in thickness as well as in diameter and size of hole, and are cut off from the

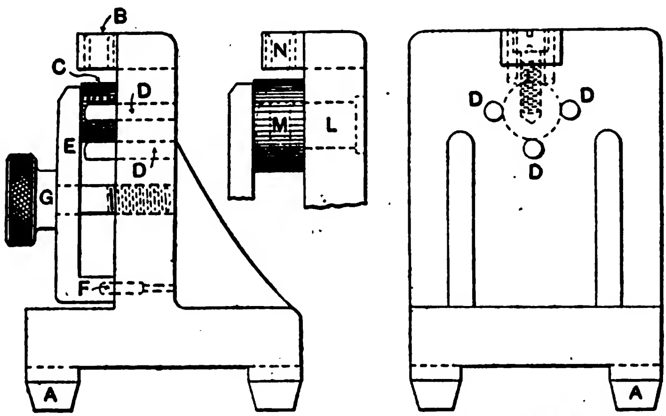


Fig. 42. Jig for Drilling Set-screw Holes in Collars

bar on the cold saw. There being a three-spindle gang drill in the shop, which was idle part of the time, it was decided to make use of it in the production of these collars. Four jigs like the one shown in the cut were made. They were made to take any diameter or thickness of collars within their range. The body of the jig is a square block of steel, with the hole to receive the collars exactly in the center. The lower end is threaded left-hand to receive the piece *B*, which has a square hole in the center to receive the wrench *C*. The ring *D* is bored taper, and fits the collar operated upon at the top end only, so that the collars will drop out of the jig easily. Different rings are made to fit collars of different diameters, and are just an easy drive fit in *A*, the body of the jig. They are driven out with a soft punch through hole *E* in piece *A*. Drill bushings *F* are also interchangeable. Piece *G* is a distance piece used when drilling thin collars in order to avoid screwing piece *B* into the jig too far. It is apparent from the cut that these pieces are made to fit the collar at one end, and beveled at the other to center in piece *B*. The reason piece *B* is threaded left-hand is as follows: If the collar operated upon should turn in

* C. H. Rowe, January, 1903.

the jig, the piece *B*, taking the thrust, would also turn, and being threaded left-hand would thereby tighten the collar in the jig. Piece *H* is a channel iron the function of which is to hold the jigs while refilling. In operation, one of the jigs is placed upon the drill press table under each spindle between flat strips *I*, which keep the jigs from turning, at the same time leaving them free to be removed for refilling. It will be seen that by having four jigs, and a three-spindle machine, by timing them so that they will finish the holes one after the other, it will give plenty of time to refill the fourth jig, and thereby, with an extra drill or two kept sharpened by the tool grinder, the

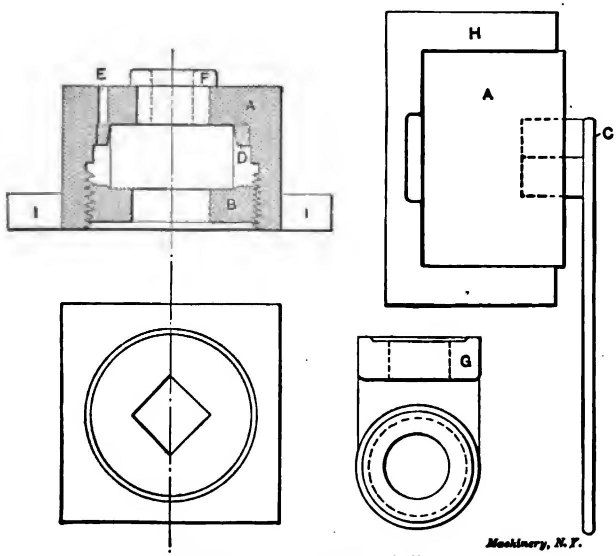


Fig. 43. Jig for Drilling Collars

machine may be kept in constant operation. This machine is equipped with a pump keeping a constant flow of cutting fluid on the drills. As this machine is also handled by comparatively cheap labor, a saving of almost 75 per cent was shown by actual test over methods previously employed in producing these collars on a turret lathe.

If it were not possible to use four jigs at a time of the kind just described, three being in operation, while one is in the hands of the operator for removing the drilled piece and inserting a new one, there would be one serious objection to the design of the jig shown. The time required for unscrewing, and again tightening, the clamping collar *B*, being threaded for its full length into body *A*, would be too long to permit rapid work. Therefore, in a case where but one jig could be used, the clamping device should be arranged so that the drilled piece can be removed, and a new one clamped in place instantly. This can be accomplished by some kind of a hinged or swinging cover, provided with a threaded binder; one half turn of the binder would be sufficient to clamp the work. In the case in hand, however, the sys-

tem of using the jigs makes this objection of less consequence, as the operator has plenty of time to attend to one jig while the collars in the others are being drilled.

Flange Drilling Jigs

Two examples of flange drill jigs are given in Figs. 44 and 45. The jig in Fig. 44 is of the simplest form for this kind of work, being merely a templet, while Fig. 45 shows the appearance and application of a more universal device, provided with an indexing plate. In cases where flanges and fittings are to be interchangeable, or to be duplicated at different times, the only accurate method of drilling such fittings is, of course, by means of a jig or templet which prevents any error arising when such parts are duplicated.

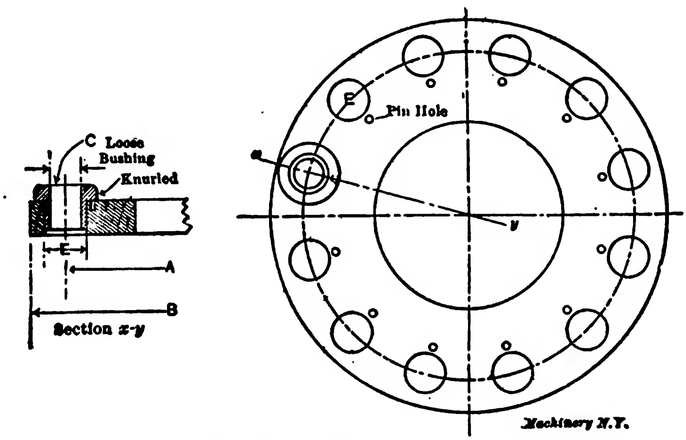


Fig. 44. Templet Jig for Drilling Flanges

The templet, Fig. 44, combines simplicity and cheapness. The ring proper may be made from a companion flange, the size for which the templet is to be used, by cutting off the head and finishing all over, the thickness being approximately one inch. Diameter *B* is made equal to the outside diameter of the flange, and *A* is the diameter of the bolt circle. A removable bushing, such as shown in section *x-y*, is used and moved from hole to hole as required. The advantage of this loose bushing over a stationary one in each hole is obvious, lessening the cost of the templet more than one-half. The bushing is made from machine steel, knurled where indicated, and hardened. The small pin prevents the bushing from revolving in its hole with the drill. In such cases where a drilling job calls for the same number of bolts in the same bolt circle, but different sizes of bolts, all that is necessary is to have two bushings, with the same diameter *E*, while *C* is made to correspond with the diameter of holes required.*

In Fig. 45 an adjustable type of jig and the work for which it is used are shown. As the number of holes in the work to be drilled, as

* Calvin B. Ross, May, 1906.

well as the diameter, varies, it would cost considerable to make individual jigs to do the work. The features of this jig are a small center plate, provided with holes for indexing, as shown at the center of the cut, and a removable arm which carries the drill bushing. The index plate is held in position by a nut on the under side of the work, and the position of the arm is fixed by a plug or pin which passes through the arm and into the plate. The bolt at the outer end of the arm is made of a suitable form to clamp on the under side of the work, and is tightened by the handle shown, which avoids the use of a wrench.

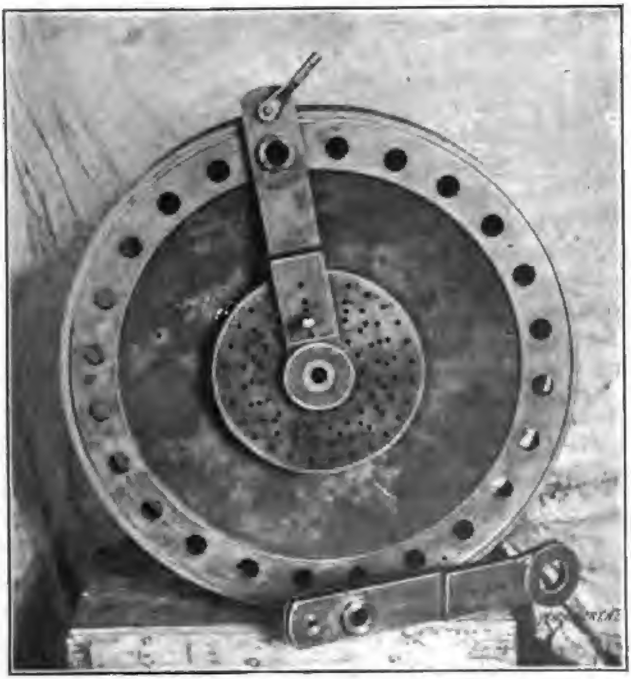


Fig. 45. Adjustable Flange Drilling Jig

By loosening this handle and withdrawing the locating plug, the arm can be turned to the next division, the plug inserted and the hole drilled. Different diameters may be drilled by using arms of suitable length, the same dividing plate answering for a wide range of sizes.*

Jigs of the description shown in the cuts, Figs. 44 and 45, are, of course, not intended for extreme accuracy, but rather for combining the objects of rapid production of work within commercial limits of accuracy, cheapness of tools, and possibility of accommodating a wide range of work with the same devices.

Adjustable Jigs

It is not always possible to provide jigs with adjustable features, particularly not when a great degree of accuracy is required. A great

* M. A. Palmer, June, 1907.

many operations in the shop, however, permit of so wide a limit of error that fairly accurate jigs can be designed which, having a certain degree of flexibility, will accommodate a variety of work. These jigs are valuable in a double measure. In the first place they save a great deal of outlay for individual jigs, and, secondly, many a little job, for which no individual jig would be warranted, may be drilled in an adjustable jig at a great saving of time and gain in accuracy.

The jig shown in Fig. 46, in use in the W. F. & John Barnes shops, Rockford, Ill., is designed with the purpose of securing adjustability, so as to adapt the jig to pieces of different shapes and dimensions. The base piece *A* supports an upright *F*, to which the knee, *E*, is bolted. This knee holds the drill bushing and is tongued and grooved to the

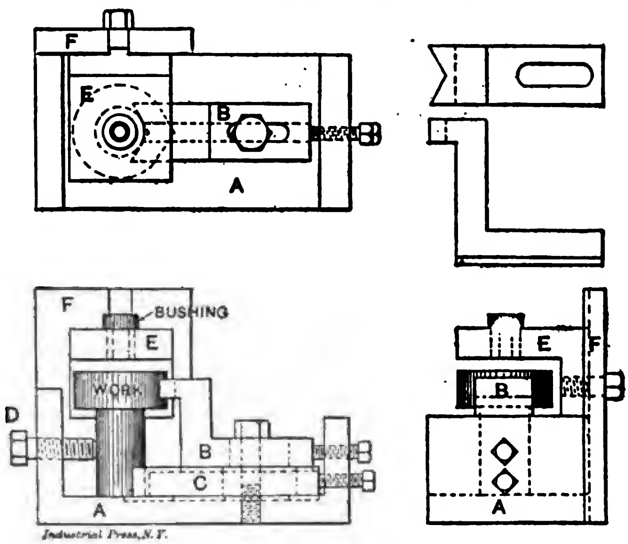


Fig. 46. Adjustable Drill Jig

upright so that it may be raised or lowered for work of different heights. The work is held by two slides, *B* and *C*, and a set-screw *D*. The lower slide, *C*, has a tongue fitting in a groove in the base, and one end is V-shaped to give support to the lower end of the work, against which it is made to bear. The slide *B* has a tongue fitting in a groove in the top of the lower slide, and may thus be adjusted independently of the latter.

An adjustable jig also provided with an indexing feature, is shown in Fig. 47. This jig is intended for drilling the clearance holes in small threading dies. As these holes are located on different distances from the center according to the diameter of the thread the die is intended to cut, one jig would be necessary for each diameter of thread in the die, although the outside dimensions of the die blanks are the same for wide ranges of diameters of thread. To overcome the necessity of so many individual jigs, an adjustable strap or slide *C* is pro-

vided, which can be adjusted to drill holes at different radii from the center of the blank, and will locate the center hole in the blank when a mark on the slide coincides with the "center line" graduation on the holder plate. The die blank is placed in holder *B*, being secured therein by the set-screws located as shown. This holder is readily rotated, as it is knurled on the edge of the flanges. It has four equally spaced locating holes, into which locating pin *D* enters.*

Miscellaneous Examples of Drill Jigs

A type of drilling jig containing features that merit the attention of the jig designer is shown in Fig. 49. One often sees expensive and complicated jigs used where one of this type would have done as well. In some shops this type has reached a high state of development, due

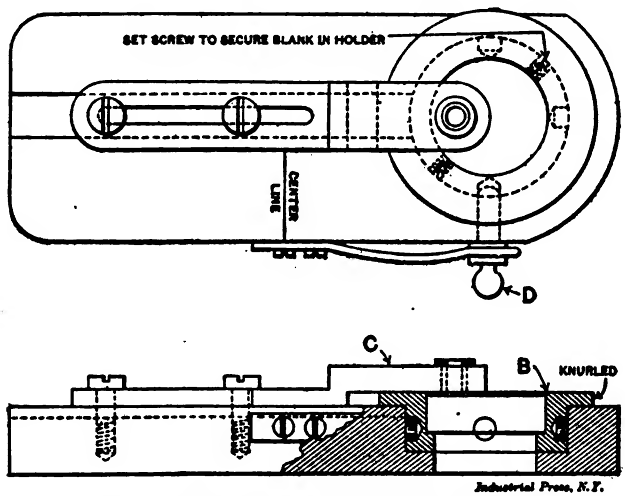


Fig. 47. Adjustable Jig for Drilling Threading Dies

to conditions that favor the adoption of a cheap and quickly made jig, namely: A constantly changing product, few pieces to be drilled of each kind, and the fact that the jigs are always wanted in a hurry. In designing jigs under these conditions, the problem resolves itself into building a cheap jig, and not accumulating a large number of useless patterns.

Fig. 48 shows the piece to be drilled and detail of clamp and feet. The plan and side views of the jig, with the work in position, are shown in Fig. 49, in which cut the jig is shown bottom side up. A cast-iron plate A is used, in which the required number of holes are drilled for the insertion of hardened bushings, and there are two locating pins, shown in the plan view at *b b*. *C* is a locating and clamping plate which is kept central by the four pins *d*. The V in the clamping plate locates the work in a central position, and as the plate also

* I. B. Niemand, February, 1902.

extends over the top of the work and clamps down upon it, it holds the work securely in place. The clamp is bolted to the plate by the screw *h*, and the work is clamped by screw *g* at the other end. Four

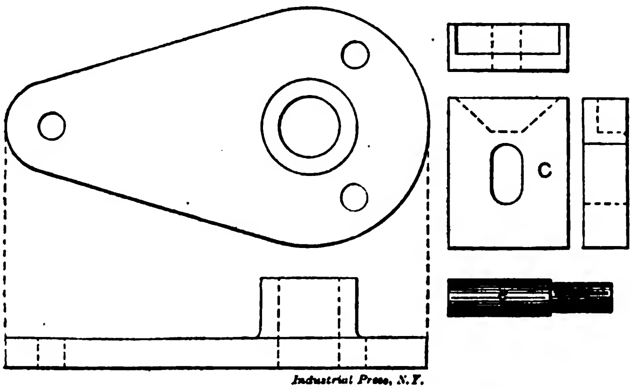


Fig. 48. Piece to be Drilled in Jig, Fig. 49, and Detail of Clamp and Feet

legs *c* support the body plate *A*, and raise it up high enough so that the work clears the table when the jig is placed in position for drilling. The oblong hole in the plate *C* permits the clamp to be moved back far enough to get the work in and out of the jig.

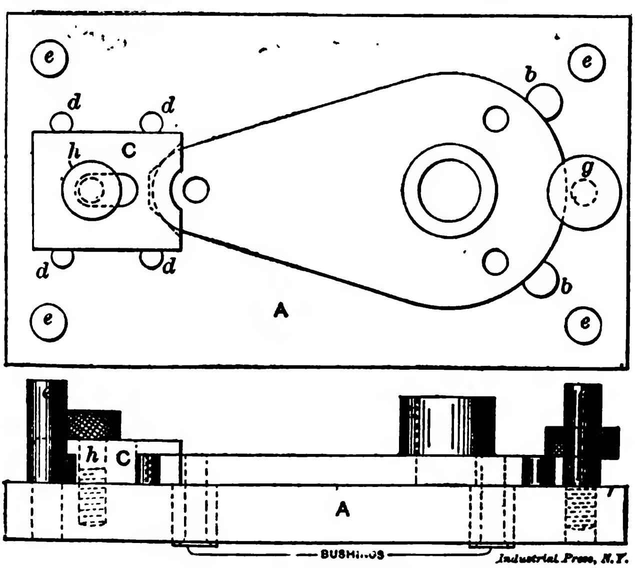


Fig. 49. Jig for Drilling Piece Shown in Fig. 48, with Work in Position

Large size plates, all planed up, may be kept in stock for the jig bodies so that pieces of the required size can be readily cut off when

needed. This jig is very accurate, as with it the work can be brought close to the plate containing the drill bushings.*

The drill jig shown in Fig. 51 has proved very efficient for maintaining uniformity in the pieces drilled in this jig, one of which is shown in Fig. 50. For the work it is intended to do, this jig is rigid and simple and is designed to withstand the severe handling that a tool

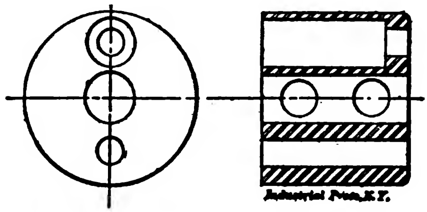


Fig. 50. Work to be Drilled in Jig, Fig. 51

of this kind usually receives from unskilled workmen. The pieces to be drilled are first turned in the lathe to the proper size and length, and the hole through the center is drilled at the same time. The object of the jig is to drill the side holes and the two end holes, which are diametrically opposite, one of them being stopped off at ⅛ inch from the bottom and continued through with a smaller size of drill.

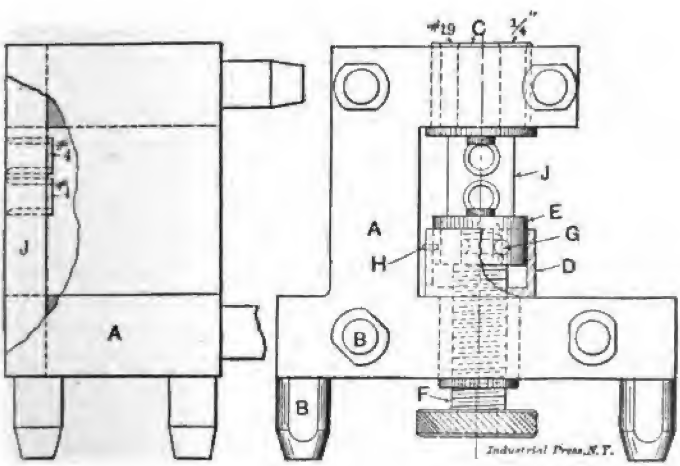


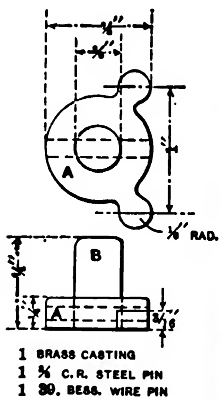
Fig. 51. Jig for Drilling Work shown in Fig. 50

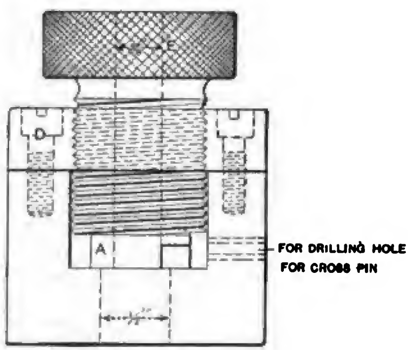
The jig consists of an L-shaped casting, *A*, which is supported on its bottom and side by the steel legs, *BB*, the faces of which are hardened and lapped true. A hole is drilled straight through the jig from top to bottom, and into the top of this hole is forced the bushing, *C*, of tool steel, having a No. 19 and a ¼-inch hole, and also a guide for one end of the work projecting at the center on the lower side. The bushing

* Louis Meyers, February, 1902.

C is forced into the jig from the inside until the shoulder bears firmly against the upper arm of the jig. This combined bushing and guide is made in a single piece, instead of inserting drill bushings and a guide piece separately, because the variation allowed for the holes is greater than any that is likely to be incurred in the hardening of the bushing.

Fitted tightly in the hole in the base of the jig is the sleeve, *D*, which carries a traversing piece, *E*, with a guide point on one end directly opposite and like the one in the upper bushing. These guides fit the hole in the work, which is advanced or withdrawn by means of the screw *F*, which is fastened to the piece *E* by the pin, *G*, introduced in such a location that the side rests in a round groove on the upper end of the screw, attaching it thereto and at the same time permitting it to rotate freely. The end of a small pin, *H*, enters a spline in the side of *E* and checks any tendency to revolve when the screw is being turned. A knurled head is pinned and riveted on the





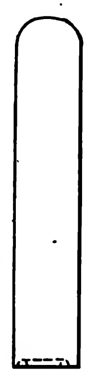


Fig. 52 Fig. 53 Fig. 54

Drilling and Assembling Jig

end of *F*. A strip of machine steel, *J*, of sufficient length to extend from top to bottom of the jig, is seated in a rectangular milled channel and fastened by screws and dowel pins. The side holes are carefully located in this strip, and two hardened and ground bushings for No. 4 drills are pressed in.

When in use, the work is slipped on the upper guide point, and, when the piece *E* is advanced by the hand screw, it is held firmly in place, being properly located in relation to the bushings by the center hole. The piece is then drilled as in ordinary jig drilling, the finished piece being removed by simply loosening up the hand screw. The piece *E*, with the exception of the guide on its end, is left soft for the point of the drills to enter the necessary depth for clearance.*

* C. H. Rowe, December, 1903.

Drilling and Assembling Jig

Sometimes drill jigs are designed for the performing of other operations in connection with the work than that of drilling alone. In Fig. 53 is shown a combined drilling and assembling jig which was designed and made for the purpose of facilitating the manufacture of the part shown in detail in Fig. 52. This detail consists of a brass casting *A* having a small machine steel stud *B* driven into its center and securely held against turning by a small bessemer wire pin through both casting and stud.

During the ordinary course of manufacturing with a plain drilling jig some difficulty was experienced in driving the studs squarely into the casting, thereby making it impossible to replace the pieces in their proper position in the jig in order to drill the small pin holes. To overcome this difficulty and insure the production of interchangeable work, the jig shown was designed to drill the necessary two holes before removing the part from the jig. It is very simple in construction, consisting of a cast iron body *C*, and a soft steel cover *D*, fitted with a tool steel screw bushing *E* for locating and fastening the casting in its proper position for drilling. The work is slipped in and removed from the front of the jig which is open, as shown.

To relieve the shearing strain on the small cross pin, it is necessary that the 3/8-inch hole shall be drilled a trifle small in order to make a good fit on the stud. This is accomplished by using a 3/8-inch drill that has been almost entirely used up and is therefore about 0.373 inch in diameter, thus avoiding the use of letter size or other drills that are not standard. After drilling, the jig is turned bottom side up and the stud inserted through the 1/2-inch hole in the bottom and driven home with the aid of the punch shown in Fig. 54. This is simply a piece of 1/2-inch drill rod having a groove turned at one end to clear the burr made by the drill. It is evident that when driven in this manner, the stud must go in square, and when the punch strikes the brass casting in the jig the stud has been driven to its proper depth, that is, flush with the bottom of the brass casting. The small pin hole is then drilled and the finished part removed by unscrewing the bushing.*

This jig permits rapid work, on account of its simple and efficient device for clamping the screw bushing. Clamping devices in jigs should always be designed with the object of very rapid tightening and releasing. This is particularly important in cases where only one or a few small holes are drilled in a piece, as then, if the clamping of the work consumes a rather long time, it often happens that most of the operator's time is spent in unscrewing and tightening long threaded studs or screw bushings, while the drilling operation itself takes but a trifle of the time, and the machine is, in fact, idle the greater part of the working day. Rapid insertion of work in jigs, and quick acting clamping devices, constitute one of the chief principles in jig design.

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* H. J. Bachmann, December, 1905.

Simplicity in Jig Design

Another of the chief characteristics in jig design, which should be aimed at as much as possible, is simplicity. It is comparatively easy to design a complicated drill jig for almost any work, and one of the main differences between the amateur and the experienced jig designer is the latter's ability to attain, by simple means, the same results, and the same accuracy, as the former reaches by elaborate devices.

An example of a simple jig which performs the work for which it is intended as satisfactorily as a more complicated tool, is shown in Fig. 55. The work to be drilled is shown at the top in perspective. At *A* is a ⅞-inch tapped hole in a curved surface, as shown; *a a* are two

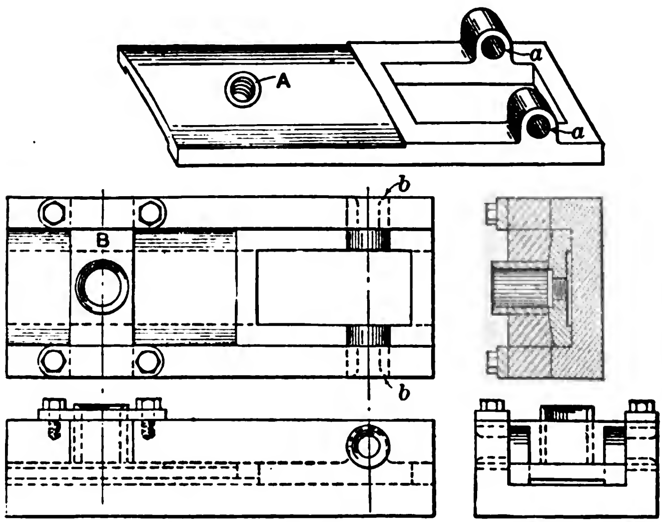


Fig. 55. Simple Design of Drill Jig

½-inch holes in the ears, which must be 7 inches from center to center from hole *A*. A cast iron jig body, of the right size to hold the piece of work inside, was made, and bushings *b b* inserted for drilling the holes in the ears. For drilling the ⅞-inch holes *A*, a cross-piece *B* was fitted into recesses cut in the sides of the jig body and this cross-piece carried a bushing, as shown. This cross-piece was held in place by two straps, as indicated. As the hole had to be countersunk, a combined drill and countersink was made, which did both operations at one cut. The work is pushed into the jig from the end, and some clamping arrangement, two C-clamps, for instance, will serve to hold it in position while drilling.*

Jigs for Drilling Rough Castings

There is a great difference in the principles of jig design applying to pieces of work which have finished surfaces from which the work may be located, and castings which are drilled directly as they come

* Frank C. Hudson, May, 1902.

from the foundry. It is not very difficult to design a jig when there is some part of the casting finished to size, but when there is practically nothing to start from, it becomes quite a different matter. If we are to judge from the number of discarded jigs in the shops, it seems that quite a few tool designers have "fallen down" on this problem.

One principal feature of these jigs is the screw bushings, two of which are shown enlarged in Fig. 58. By screwing down on the bush-

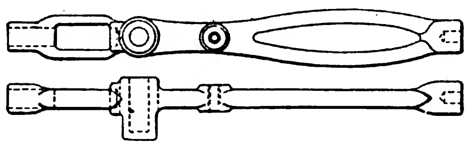


Fig. 56. Work to be Drilled in Jig, Fig. 57

ing the casting is clamped between the screw bushing and a plain bushing in the bottom of the jigs. Thus it will be seen that these bushings perform the double function of locating the hole and also holding the casting securely in its proper position in the jig. When only one end of the boss is accessible, the plain bushing cannot be used, and other means must be devised to back up the thrust of the screw bushing. Being movable, screw bushings will take care of any reasonable variation in the size of the castings and also insure that the hole shall be drilled in the center of the boss, the bushing being recessed

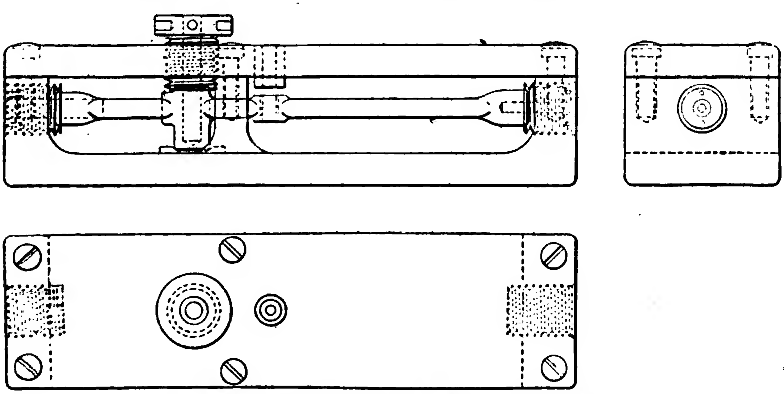


Fig. 57. Jig for Drilling Work Shown in Fig. 56

in the portion binding against the boss in order to center it. This latter condition is very desirable in work of this kind, for the sake of appearance and strength. In this form, screw bushings are rendered applicable to all forms of castings having any kind of a circular projection or boss over which the bushings may be fitted, as shown in the cuts, Figs. 57 and 60.

When headless bushings are necessary (as on both ends of the jig, Fig. 57), they are tightened down with a spanner, whereas a plain drill rod pin is sufficient for the other. When both ends of the boss are held by bushings, the holes to receive these bushings must be in

line, and when they are so aligned, it is impossible for the hole to come out of center on either end of the boss. The simplest and safest way to align these holes is to run a single-pointed boring bar through the screw bushing into the bottom of the jig, after the screw bushing has been fitted to the jig, the shank of the boring bar, of course, being a good fit in the hole of the screw bushing, which has been previously lapped to size. On the larger sizes of bushings, it has been found advantageous to use a good quality of machine steel, case-hardened and having a smaller tool steel bushing inserted in the center. When made

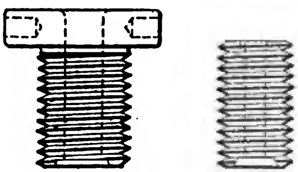


Fig. 58. Screw Bushings

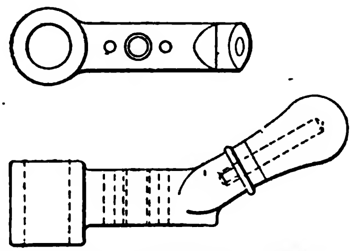


Fig. 59. Work to be Drilled in Jig, Fig. 60

entirely from tool steel, the distortion in hardening is too great to allow a good fit, which is essential on the threaded portion. The bodies of the jig should be made of cast iron, cradle-shaped, and cut out where possible, to facilitate cleaning. The covers which hold the screw bushings should be of machine steel, held in place by means of screws and dowels.

Two examples of jigs of this class are shown. The larger jig, Fig. 57, was designed for drilling the breast drill frame shown in Fig. 56.

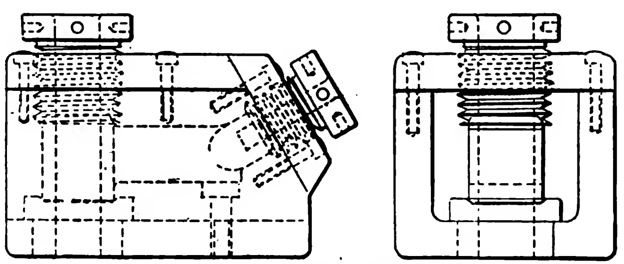


Fig. 60. Jig for Drilling Work Shown in Fig. 59

The casting is clamped by the large bushing first, and then the smaller bushings on the ends are brought up just tight enough not to cause any spring in the casting. There are two holes in this frame which must be reamed square with each other. After trying unsuccessfully to ream the holes by hand after drilling in the jig, the holes were reamed in the jig as follows: The hole in the bushing was made the exact size of the hole to be reamed in the casting. A drill of this size was used to spot the hole, following with a reamer drill, and lastly with a rose reamer, making in every respect a satisfactory job.

The difficulty with a jig of this design, in general, is that the castings will warp, throwing them out of true, and it is then not possible to locate them as described. The Hoefer Mfg. Company, Freeport, Ill., has found that in drilling pieces of this character, the stop underneath, in the center of the jig, in which the boss of the casting to be drilled rests, should be made adjustable, with a spring under the stop. The tension of this spring should be just enough to carry the weight of the piece. When placing the piece in the jig the two end bushings are then adjusted so that the boss of the work centers in the stop. By

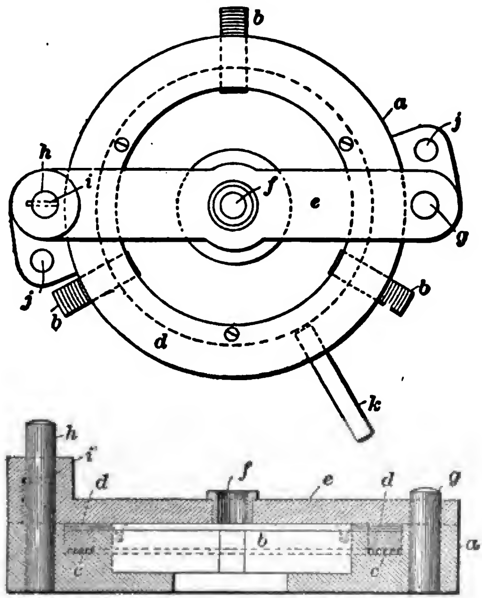


Fig. 61. Jig for Drilling and Boring Cast Gears

means of a clamping screw this stop is then held rigidly in place, and the drilled bushing finally screwed down tightly from the top.

The smaller jig, shown in Fig. 60, designed for the simple lever shown in Fig. 59, presents no difficulties beyond the drilling and tapping of the hole for the wooden handle at an angle of 30 degrees. An adjustable stud screwed into the bottom of the jig resists the pressure of the bushing on the angle. In this jig it is also necessary to clamp the larger boss first, so that when the smaller bushing is tightened, there will be no tendency to displace the casting. The same procedure was followed in the case of the tapped hole as in the case of the reamed hole in the jig previously described, namely: full size drill to spot, tap drill and then the tap itself. This latter was operated by means of a tapping attachment with friction clutch. It is hardly necessary to say that these jigs are most profitably employed in connection with a multiple-spindle drill press.*

* H. J. Bachmann, December, 1904.

Jig for Drilling and Boring Gears with Cast Teeth

Cast spur gears should be held from the outer ends of the teeth at three points as nearly equally spaced as possible. The holding should be done by jaws moving to and from the center. The outer ends of the teeth are selected because they are less liable to distortion by the washing of sand and by swelling than other parts of the teeth, and any slight lumps are much more likely to be removed in the tumbling barrel from the ends than elsewhere. Again, it is much more convenient to hold them from these points than otherwise. If three equally spaced points on the periphery of a gear are held true with the jig

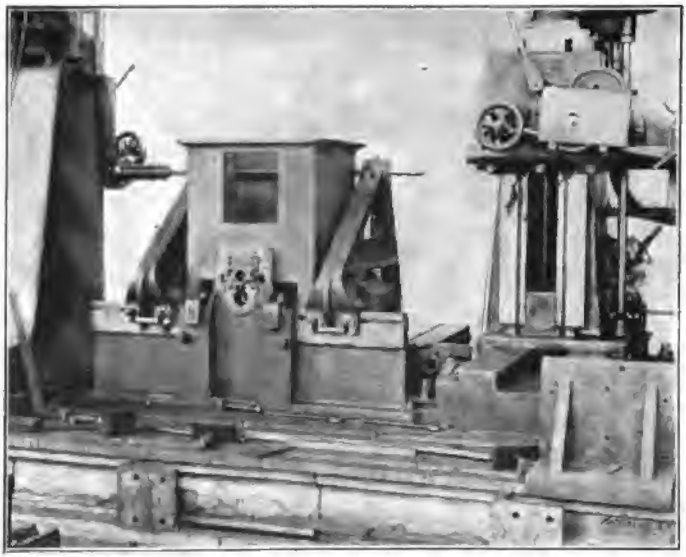


Fig. 62. Large Drilling and Boring Jig for Machine Beds

bushing, all intermediate points must be well located for the boring operation.

The manner of holding as described may be accomplished by several devices. One of these is a special form of scroll chuck. The same jig chuck may be made to accommodate different sizes of gears within a limited range with, it may be, the exchange of bushings.

Fig. 61 shows top and sectional views of such a jig. Referring to this figure, *a* is the main body casting, which is planed to receive the three steel jaws *b* and turned to admit the scroll ring which will be seen at *c*, while *d* is a steel ring used to retain the jaws and scroll. At *e* is seen the cross-bar for the support of the bushing *f*. This cross-bar is held in place by two guide pins *g* and *h*. The latter is longer than the former, so that when a gear is to be removed from the jig, the cross-bar may be raised only sufficiently to clear the short guide pin and then swung aside upon the longer one. The end of the cross-bar engaging the long pin is provided with a boss of sufficient length

to insure a parallel movement and prevent cramping. At *i* will be noticed a pin driven into the tail guide pin and left projecting into a slot. This acts as a stop to prevent the cross-bar from slipping down again when swung aside until again brought into line with the short guide pin. At *j* are seen holes for attaching the jig to the drill press table. A handle for revolving the scroll ring is shown at *k*.*

Drilling and Boring Jig for Machine Beds

The jigs shown hitherto have, in general, been intended for work of comparatively small dimensions. Modern machine manufacture, however, has developed jigs of unusual dimensions for very large pieces of work. The jig shown in Fig. 62 is used at the works of the Landis Tool Co., Waynesboro, Pa., for drilling and boring the beds of their smallest size grinding machines. The cut shows the work in progress on a large horizontal boring mill. The jig consists of a base provided with an adjustable plate for drilling the holes in the front, and adjustable brackets for guiding the bars for boring the ends of the bed. The base consists of a heavy casting, planed at the top, so as to correspond with the planed portion of the top of the bed, so that the latter may be laid bottom up on this base and located transversely by the planed lip on the front of the bed, suitable clamps being provided to hold it firmly in position. At the front of the base of the jig is a vertically projecting flange or apron of sufficient size, and so shaped as to conform to the shape required for locating most of the holes in the front of the bed; at the back part of the base is a smaller flange adapted for carrying a bushing for guiding the bar for one of the larger of these holes. Suitable T-slots are provided in the base for bolting on the various parts, and at the bottom two right-angle grooves are planed to provide for a tongue for locating on the floorplate of the boring mill. This jig is designed to accommodate two sizes of beds or similar cross sections but of different lengths, the difference being such as to only affect the location of the end brackets and some of the holes in the front of the bed. To provide for the difference of these latter holes, the adjustable plate in the front is so designed that it can be located by dowel pins in either of two positions required, and is provided with slots for clamping bolts. When boring the holes in the ends of the bed, the base of the jig is, of course, turned from the position that it has, when the front holes are bored, to the position shown in the cut. The end brackets are clamped in place, being located on the finished surface of the base. T-slots are provided so that these brackets may be shifted in or out to accommodate the different length of the beds.†

Jigs with Pneumatic Clamping Devices

During the last few years compressed air has more and more become one of the necessary adjuncts of the machine shop, and many firms employ it extensively in the operation of automatic machinery and special tools. The line cuts Figs. 63 and 65 and the half-tone Fig. 64 show a pneumatic clamp drilling jig which was designed for holding

* Cyril B. Clark, June, 1904.
† H. F. Noyes, March, 1907.

small castings, pinions, spur gears, sprockets, pulleys, etc., for reaming or drilling. This type of jig is used with great success in one of the largest manufacturing concerns in Chicago. Formerly castings of the nature named were held in a jig, using a screw bushing mounted in a swinging arm to hold the work while drilling; the arm was swung around over the casting and the bushing was screwed down onto the work. Frequently the operator would neglect to screw the bushing

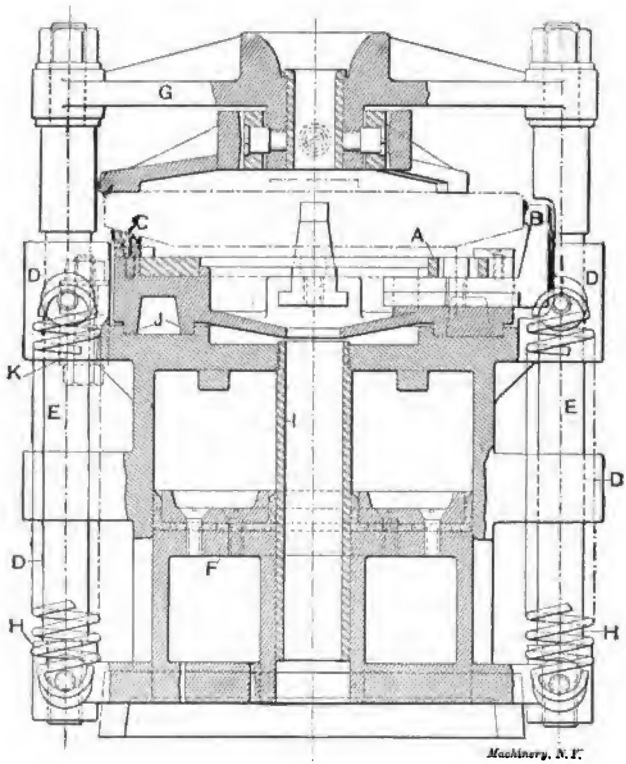


Fig. 63. Vertical Section of Pneumatic Clamping Jig

down tightly against the work, with the resultant of a bad job of drilling and a spoiled piece. In any case there was considerable time lost in operating the jig.

The air clamping drilling jig shown in section in Fig. 63 was designed to decrease the time required to operate the jig and to improve the character of the work done. The cut shows how a bevel gear is held. The gear rests on the inclined face *C*, and between three chuck jaws. Beneath the casting is a ring, *A*, having three cam eccentric slots which move the jaws *B* toward or away from the center when the ring is turned by a suitable handle. With this jig the operator needs only to turn an air valve handle to hold the work securely and

in the central position. To hold spur gears, a centering piece is used, similar to the one shown for bevel gears in Fig. 63, with the exception that the surface *C* is made flat, the jaws then being used alone to center the work.

The jig includes a cylinder having two lugs or ears *D*, which encircle the guides *E*. These guides connect the piston *F* with the cross-arm or yoke *G*, which holds the drill bushing. The admission of air to the

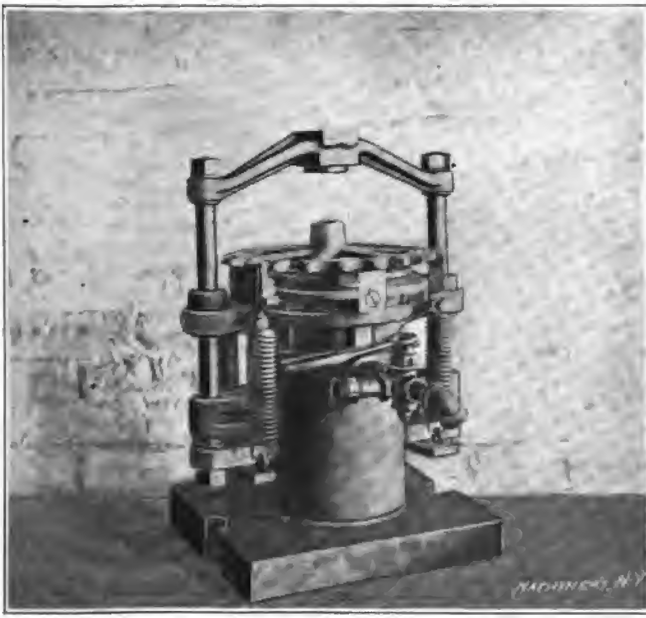


Fig. 64. Pneumatic Clamping Jig used for Drilling Sprocket Wheel

cylinder forces the yoke and bushing down on the work and holds it there until the piece is finished. The air is then released and the tension springs *H*, of which four are provided, pull the piston and the connected cross-arm up and release the work. Compressed air is admitted in the side of the cylinder through a pipe in which is fitted an ordinary three-way valve. The pipe *I* in the center of the cylinder is an important feature, as it permits chips to fall through the jig at the bottom instead of collecting on the top. What few chips accumulate on the top are removed by a hose leading from the exhaust port of the valve and directed against the top of the cylinder, thereby blowing the chips away with each exhaust. The centering device is made different, of course, for different pieces, Fig. 63 showing one for a "flat" bevel gear; and each pattern of pinion, gear or sprocket has to have a corresponding piece *C*. The cylinder has an annular groove *J* turned in the top and made concentric with the axis of the cylinder and of the drill jig. The centering device has two projections which fit the cylin-

der top and groove. This makes the air cylinder conveniently interchangeable with any number of centering devices, the centering device being removed quickly so that there is little time lost in making changes, the clamping being a simple matter. The cylinder has three lugs *K* with open slots for bolts, these matching with three lugs on the centering device and constituting the clamping arrangement for the centering piece. When the centering piece is to be changed, the three bolts are loosened, slipped out of the slots, and the centering piece is lifted out and exchanged for another.

If the drill bushing has to be changed, the yoke *G* is taken off and replaced by another, for it is generally desirable to have a yoke with

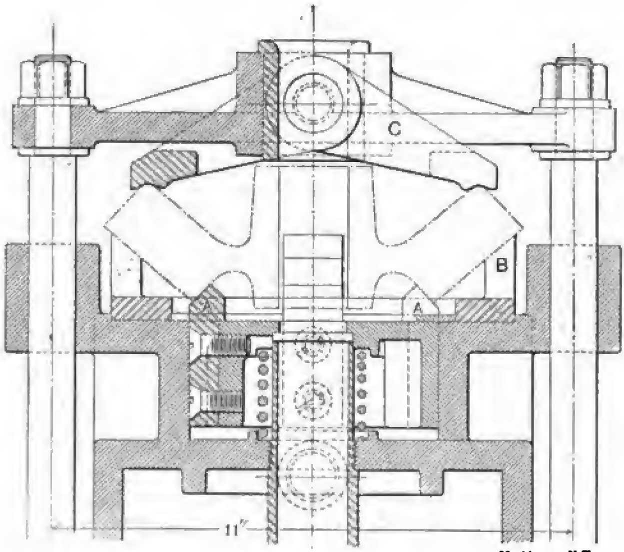


Fig. 65. Vertical Section of Pneumatic Jig Fitted with Equalizing Centering Device

its own bushing for each job. With small work the yoke simply has a bushing driven from the bottom, as illustrated in the half-tone Fig. 64, and the bushing alone presses against the work, but for larger work, which should be held down at three places on the rim, the yoke and clamp are connected with a universal joint as illustrated in Fig. 63, thus insuring equal pressure on the three clamping points.

Fig. 65 is a centering device, used on the air-cylinder, in which there is a float. This float rests on a heavy spring, and on the float are three lugs *A* which support the gear casting. This device centers the casting, while the yoke is pulled down by air pressure until the gear rests on the three stationary surfaces *B*. The yoke with its equalizing saddle *C* holds the bevel gear firmly while drilling.*

In the design of all devices using compressed air, care should be taken to economize as much as possible with the air, making the spaces

* O. C. Bornholt, April, 1907.

it has to fill as small as possible. In the jig shown this has not been thoroughly taken into consideration. The long motion of the piston, entirely operated by air, makes it necessary to fill a great space with air each time the work is clamped. In such cases it is usually possible to move the clamp down upon the work with a mechanical movement requiring no air, and then effect only the actual clamping by the compressed air, in which case it would probably not be necessary to use one-tenth the amount of air now used in the jig

CHAPTER IV

DIMENSIONS OF STANDARD JIG BUSHINGS

In the design of drill jigs there is little save experience and judgment to guide the draftsman when determining the dimensions of the drill bushings. This often results in having bushings for the same size of drill made with widely varying dimensions as to length and outside diameters. If, on the other hand, some standard is adopted

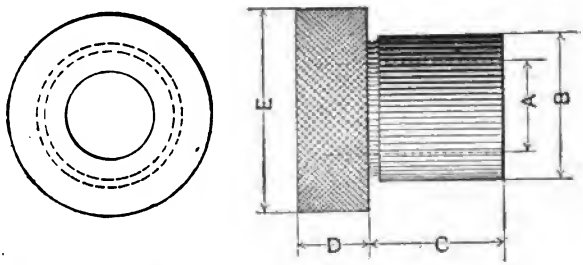


TABLE 1. DIMENSIONS FOR STANDARD FIXED JIG BUSHINGS

Size Drill. A	B	C Short.	C Med.	C Long.	D	E
60	1/4	1/4	3/8	5/8	3/32	5/16
3/16	3/8	1/4	3/8	5/8	3/32	7/16
1/4	1/2	1/4	3/8	5/8	3/32	5/8
3/8	5/8	3/8	1/2	5/8	1/8	3/4
1/2	3/4	3/8	5/8	7/8	1/8	7/8
9/16	13/16	1/2	3/4	1 1/8	1/8	1
5/8	7/8	1/2	3/4	1 1/8	5/32	1 1/16
3/4	1	1/2	3/4	1 1/4	5/32	1 3/16
7/8	1 1/8	1/2	3/4	1 1/8	3/16	1 5/16
15/16	1 3/16	5/8	7/8	1 1/4	3/16	1 7/16
1	1 1/4	5/8	7/8	1 1/4	1/4	1 1/2
1 1/16	1 5/16	5/8	7/8	1 3/8	1/4	1 9/16
1 1/8	1 7/16	5/8	7/8	1 3/8	1/4	1 3/4
1 1/4	1 5/8	5/8	7/8	1 3/8	1/4	1 15/16

and adhered to, uniformity will be insured and the toolmaker can make up bushings in leisure moments, knowing that they will be available whenever a rush job of jig work comes along. Tables 1 and 2, which give dimensions of bushings, are now used by a large manufacturing concern, and furnish an excellent guide for any draftsman designing jigs where no standard has been adopted.

Table 1 gives dimensions for bushings which are to remain in the jigs permanently, and in making these bushings the external diameter given in the column *B* would be made a driving fit in the hole in

the jig. Table 2 gives dimensions for removable bushings, and in this case the outside diameter would be made a light sliding fit in the hole. In both tables the column *A* indicates the size of drill for which the

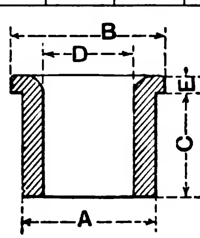
TABLE 2. DIMENSIONS FOR STANDARD REMOVABLE JIG BUSHINGS

Size Drill. A	B	C Short.	C Med.	C Long.	D	E
60 to 40	5/16	3/8	1/2	3/4	1/4	9/16
40 to 26	7/16	1/2	5/8	3/4	5/16	3/4
26 to 1	7/16	1/2	5/8	7/8	5/16	3/4
7/32 to 19/64	1/2	1/2	3/4	1	3/8	13/16
5/16 to 3/8	5/8	5/8	7/8	1 1/4	3/8	1
25/64 to 7/16	11/16	5/8	7/8	1 1/4	7/16	1 1/8
29/64 to 17/32	3/4	5/8	7/8	1 1/4	7/16	1 1/8
35/64 to 39/64	7/8	5/8	7/8	1 1/4	7/16	1 1/4
5/8 to 11/16	15/16	3/4	1	1 1/4	1/2	1 3/8
45/64 to 49/64	1	3/4	1	1 1/2	1/2	1 7/16
25/32 to 7/8	1 1/16	3/4	1	1 1/2	1/2	1 1/2
57/64 to 15/16	1 3/16	3/4	1	1 1/2	1/2	1 5/8
15/16 to 1	1 1/4	3/4	1	1 1/2	1/2	1 3/4

bushing is to be used, and the hole in the bushing would be made from 0.001 to 0.003 inch larger than nominal size. The bushing shown in the cut above Table 1 has a knurled head. Of course, the head is only knurled on removable bushings.*

TABLE 3

BUSHINGS FOR DRILLING AND REAMING JIGS									
D	A	B	C	E	D	A	B	C	E
3/16	7/16	9/16	5/8	3/32	1 1/8	2 1/4	2 1/2	1 1/2	1/4
1/4	1/2	5/8	5/8	3/32	1 1/4	2 7/16	2 11/16	1 1/2	1/4
5/16	9/16	11/16	5/8	3/32	1 3/8	2 5/8	2 7/8	1 1/2	1/4
3/8	11/16	13/16	5/8	1/8	2	2 3/4	3	1 1/2	5/16
7/16	3/4	7/8	5/8	1/8	2 1/4	3 1/8	3 3/8	1 1/2	5/16
1/2	13/16	15/16	3/4	1/8	2 1/2	3 3/8	3 5/8	1 1/2	5/16
9/16	7/8	1 1/8	3/4	1/8	2 3/4	3 5/8	3 7/8	1 1/2	5/16
5/8	1	1 3/16	3/4	1/8	3	4	4 3/8	1 1/2	5/16
11/16	1 1/16	1 1/4	3/4	1/8					
3/4	1 1/8	1 3/8	1	3/16					
13/16	1 3/16	1 7/16	1	3/16					
7/8	1 5/16	1 1/2	1	3/16					
15/16	1 3/8	1 9/16	1	3/16					
1	1 7/16	1 11/16	1 1/8	3/16					
1 1/8	1 5/8	1 7/8	1 1/8	3/16					
1 1/4	1 3/4	2	1 1/4	3/16					
1 3/8	1 15/16	2 3/16	1 1/4	3/16					
1 1/2	2 1/8	2 3/8	1 1/2	1/4					



Machinery,N.Y.

Table 3 gives the dimensions for drill bushings for a wider range of drill sizes, according to the adopted standard of a large manufactur-

* Machinery, April, 1904.

ing concern in Chicago. It will be noticed that the shoulders are much smaller than generally used. There is no real need for the shoulder of a loose or removable bushing to be larger than is necessary for a good finger hold. By keeping the shoulder dimensions down to the figures given in the table, a considerable saving of steel is effected in the larger sizes, and when this amount is multiplied by the thousands of bushings necessary in large machine shops, it becomes a very important matter. Another feature of economy possible in bushings is the use of machine steel, case-hardened, which gives as good results for some work as tool steel, and of course is far less costly, both in price per pound and in time required for working.*

Hardening Small Jig Bushings

To harden large quantities of small jig bushings without danger of cracking under the head while hardening or while driving them home, proceed as follows: Put one gallon of fish oil in a suitable metal bucket, and place this in a larger bucket of cold water. The bushings, strung about six on a wire, are heated in a small blow torch fire to a light red heat and are then quickly plunged into the oil, and kept moving around until cold. The hardness will depend upon the degree of heat given, and this can be so regulated that it will not be necessary to polish and draw bushings after hardening.†

* O. C. Bornholt, May, 1905.
† H. J. Bachmann, November, 1905.

CHAPTER V

USING JIGS TO BEST ADVANTAGE*

It may be deemed proper, in the closing chapter, to review, in general outlines, the principles of jig design, and to give some directions for getting the full value out of jigs.

Competition and the growing demand for machinery have necessitated the introduction of improved tools to reduce the cost. Jig and fixture designing has come to be a trade by itself; undoubtedly there is no branch of the mechanical business which requires so much practical experience as this particular line. A poorly designed tool is a very costly thing; hundreds of dollars can be wasted in a short time with an inferior one. On its accuracy, simplicity and quickness depend quality and quantity, hence cost of product.

There are a number of obstacles to be overcome in accurate jig and fixture designing. The clamping must be done quickly and without springing the jig or the work; then provision must be made for easy cleaning out of chips, and another very important thing is, that it must be so constructed that it will be impossible to get the work in the wrong way. It is important to make drilling jigs as light as possible. To obtain lightness, just as little metal must be used as is necessary to sustain the strain brought to bear upon the part. All metal should be so placed as to be in line with the strains exerted thereon; therefore, jigs should be box-shaped. The advantages obtained are manifold, for, while they are light, they are also easily cleaned. Some of the older manufacturers still advocate the use of heavy drilling jigs—large, cumbersome things, and slow to handle. Their reason is that a light jig will not stand the rough handling. While that is true in a way, there ought not to be any necessity for such rough usage. A proper system in the shop would overcome this.

It is customary in a good many of the large shops in the Eastern States particularly to hire green men and boys to operate the jigs and fixtures. If it is a drilling jig, especially a small one, the gang drill is set up for that purpose; each spindle in rotation is set up for its respective operation. The men that set these machines are competent machinists, and they always keep one or more machines set up for the first one who gets out of a job. They are also responsible for the quality and quantity of work turned out. For instance, a drill or reamer may get roughed up and in this manner spoil the work or a drill bushing. Therefore, it keeps the machinists in charge on a constant outlook. The operators are provided with a gage and a sample piece which is correct. They are instructed how to use it; also to try every few pieces to see that they are coming like the sample. In this manner one good man can direct the work of a dozen cheap ones.

* MACHINERY, August, 1904, and February, 1905.

In the following outline of a system for getting the most out of the tools in the shop, the word "jig" will be meant to include all jigs, templets, fixtures, appliances, etc., which aid in the rapid and accurate machining of parts. With such assumptions allowed, the necessity for some systematic scheme of management for the use and care of the jigs should be apparent. However, it is not uncommon, even in these days, when the jig is admittedly one of the main factors instrumental in developing the shops of the past (where machinery was "built"), into the shops of the present (where it is "manufactured"), to find concerns where the jigs are given no consideration beyond designing them and keeping them in a questionable state of repair. The whole tool or jig scheme, however, is so interwoven with the entire shop that the success of a system cannot be dependent entirely upon any one person, but upon the co-operation of all.

DRILLING JIG SET-F 42 C.
1 JIG
1 " LID
4 THUMB NUTS
2 SET SCREWS
6 BUSHES
TWIST DRILLS - 31/32" - 3/4" - 17/32" - 1/2"
TAP - 5/8" - 10 THREAD MACHINE
REAMER 1" MACHINE
" TAPER - SPECIAL NO. F 39

Fig. 66. List of Parts of Jig, and Tools used with same

DRILLING OPERATION SHEET F 42 C.
DRILL 31/32"
REAM 1"
REVERSE LID AND
DRILL 17/32"
TAP 5/8" - 10 THREADS
DRILL 3/4"
" 1/2"
REAM 1/2" SPEC. NO. F 39
NOTE:- CARE MUST BE TAKEN THAT CHIPS DO
NOT ACCUMULATE IN CORNERS OF JIG.
NOTE:- DO NOT TIGHTEN TOO MUCH ON SET
SCREWS AS THERE IS DANGER OF SPRINGING
WORK.

Fig. 67. List of Operations to be performed

The tool foreman is the one, after the management, who contributes most to either success or failure, and therefore his selection should be made with care. This tool foreman, as we prefer to call him, is to the modern shop what the head toolmaker was to the old-time shop, and his increased duties and responsibilities entitle him to the new title. He should possess executive as well as mechanical ability, and be broad-minded and up-to-date, for to him should be intrusted the tooling of the machines, the design, manufacture and care of the jigs, the complete control of the tool-room and the enforcement of any system the management may inaugurate. He will, however, be doomed to only partial success, if not absolute failure, without a tool-room system.

Suitable methods should prevail in the tool-room, or better, in the jig-room, whereby a workman when receiving a jig gets all the necessary tools to perform all the operations upon the piece that the jig is designed to do. It should not be necessary for him to ask for the tools separately, but simply to ask for the jig and tools for such or such an operation, designated either by name or number—preferably by number—and have them delivered to him complete. By doing this, much time will be saved, and mistakes will often be avoided. This can

be accomplished by giving each jig all the loose pieces belonging to the jig and all the special tools, the same number as the piece they are used upon. They should be indexed under this number and kept in suitably grouped compartments and the compartments conspicuously numbered so that they can be easily located. In these compartments is also kept a list, Fig. 66, showing what constitutes a complete set. When a jig is called for, reference is made to the index, if necessary, the compartment found and the complete set of jig and tools delivered with reference to the list.

Probably one-half of all jigs are designed to perform two or more operations, and when such is the case, to economize in time and often to obtain the best results in machining, each jig should have its operation sheet, Fig. 67. To illustrate why it is necessary to perform the several operations in a prearranged order, take, for instance, two holes intersecting at acute angles, such as a shaft hole and a locking rod hole, where the locking rod hole drills half out into the shaft hole. Ordinarily a workman would drill the larger or shaft hole first, and the locking rod hole afterward. This would be wrong, however, for the locking rod hole drill upon entering the shaft hole and meeting no resistance for half its diameter, would run out, and the hole would not be straight. A very handy arrangement is to have the tool sheet, Fig. 66, and the operation sheet, Fig. 67, mounted upon opposite sides of a cardboard. They should be of some convenient size, to be determined by the number of separate items it is necessary to put upon them.

It is regrettably too generally the custom to take for granted that a piece is right if it has been jigged, and in this way much work is often spoiled that could be avoided by the simple system of inspecting the first piece of every lot done in a jig and ascertaining its correctness. If the first piece is found to be correct, it is reasonably safe to assume that the rest will be. It is also well to provide printed blanks upon which defects and possible improvements in jigs are reported to the tool foreman. These are made out in duplicate by the foreman under whom the defects, etc., are discovered, he keeping the copy and sending the original to the tool-room. This method will be found to be superior to giving verbal instructions, as it is a check from one foreman to another. There is an adage which cannot be more appropriately applied than in the case of repairing jigs, and that is, "Don't put off until to-morrow what can be done to-day."

It seems hardly necessary to mention the matter of allowing repairs to be made upon jigs in any other place than the tool-room, because it is so obviously wrong that every one must see the fallacy of such a course and what a demoralized state of affairs it will lead to. In this matter there should be absolutely no margin. Whenever repairs are necessary on jigs, they should be turned over directly to the tool-room, and even the most trivial matters should be attended to by the man in charge of the jigs, as he is held responsible for results.

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